The

Tropical Agriculturist

May 1929.

EDITORIAL.

SOIL INVESTIGATIONS.

WITHIN recent years there has been a marked interest in the investigation of tropical soil problems, an interest which is due to the fact that large extents of virgin land with vast potentialities are being opened up in various parts of the tropics. In the past, no thought or attention was given to the preservation of the soil and today little remains of what once constituted the surface cover of hilly, humid, forest lands which were brought into cultivation. The destruction of the forest has thus been followed by a rapid exhaustion of the organic matter of the soil and the erosion of the surface soil with its valuable colloid material. Ceylon affords an example of this type of soil deterioration. The imperative need, however, for the prevention of further soil erosion and the increasing of the humus content of our soils is now realised, and the adoption of suitable measures for attaining these objects has become more general in the last few years. The Department of Agriculture is alive to the situation, and for some years has endeavoured to demonstrate practical methods for the solution of an important problem. In its attempts to do so, it has received valuable assistance from individual planters and the planting community in general.

Second only in importance to the question of soil erosion in Ceylon is the related problem of green-manuring which in its general aspects has formed the subject of investigation by the Department. The fact that the lack of organic matter is one of

the principal limiting factors of crop growth in Ceylon is now recognised. The investigation has included a study of the composition and "decomposability" of the more widely-grown green-manures in Ceylon and their variation with age; of their rates of decomposition and availability in relation to rainfall and temperature; of the periods of optimum nitrification and duration of their effects in the soil; of the losses of nitrogen and the effect on nitrification as a result of drying green-manures under field conditions; and of the soil-moisture relationships of green-manures In addition, a series of experiments to determine the changes in soil reaction and the carbon-nitrogen ratio of soil brought about by green-manuring has been in progress for some time. An attempt is also being made to determine the change in soil fertility (as measured by exchangeable base content, reaction and carbon and nitrogen contents) which results from the opening up of hilly forest land in rubber. In this connection reference may be made to two interesting articles reproduced in this number of *The Tropical Agriculturist* on the problem of soil changes in relation to tropical agriculture. In one, an account is given of the effects of deforestation and exposure of tropical forest lands. The other deals with the subject of the investigation of tropical forest lands. The similarity of the problem of soil deterioration in St. Lucia and Ceylon is noteworthy.

A second type of soil deterioration, common in the dry zones of the tropics, is that produced by the primitive "chena" system. The objections to the system need not be recounted here. An investigation to determine the losses of soil fertility as a result of "chena-ing" is about to be begun.

Besides the soil investigations already mentioned, a study of the important problem of green-manuring under paddy land conditions in Ceylon has been undertaken. The present issue of this journal contains a paper on the subject which should prove of value to agriculturists interested in the food supply of the Island. Another soil investigation to be taken in hand as soon as convenient is a profile study of the main types of Ceylon soils. The data obtained from these researches will be particularly useful in the interpretation of the results of carefully designed manurial trials carried out on varied crops in different parts of the country, on various soil types and under varying climatic conditions. Related to soil investigations is the question of the absorption by, and leaching of fertilisers from, Ceylon soils in relation to rainfall. A preliminary investigation of the absorption of fertilisers by some typical Ceylon soils has already been carried out, and leaching trials have been in progress for over two years.

The detailed investigation of tropical soil problems in all their aspects is an urgent need at the present time, and, as far as Ceylon is concerned, efforts are being made to meet the need.

ORIGINAL ARTICLES.

LABORATORY AND FIELD STUDIES ON GREEN-MANURING UNDER PADDY-LAND (ANAEROBIC) CONDITIONS.

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INTRODUCTION.

THE value of incorporating into paddy fields green material brought from outside or grown *in situ* is well recognised in countries where paddy is grown. In Ceylon, the practice of ploughing in green leafy material is adopted when the latter is available, but the system of raising a green-manure crop on the fields between the harvesting of one crop and the preparation of land for the next has not become general (12). In view of the importance of green-manuring in paddy cultivation and of the lack of scientific data on the subject, laboratory and field experiments were undertaken (1) to determine the rate of decomposition of green-manures under paddy-land (anaerobic) conditions, (2) to study the chemical changes taking place and to ascertain which of the decomposition products formed were of benefit to the paddy plant, (3) to determine the optimum time and conditions for ploughing in green-manures, that is, whether early or late burial is preferable, (4) to ascertain from a study of the chemical changes taking place in each case, the comparative merits of the two systems of green-manuring adopted, (5) to determine the change in soil fertility as a result of green-manuring paddy at different periods, and (6) the magnitude of the increased yields obtained. The field experiments were undertaken in co-operation with the Economic Botanist who has been responsible for the layout of the plots, the carrying out of the actual field operations, and the examination of the yield data. This aspect of the field experiments will therefore be treated by him separately. The sampling of the soils at regular intervals for chemical examination has been done by the writers, and in this paper only the results of the determinations will be dealt with. Reference will however be made to the final conclusions derived from the examination of the yield data of these and other field experiments in order to illustrate the correlation between the

chemical and yield data. The laboratory experiments were devised and carried out by the writers and were designed to supply as much information as possible on the subject of green-manuring under paddy-land conditions.

PREVIOUS WORK.

As no other food crop than paddy is grown under submerged soil (anaerobic) conditions, comparatively little attention has been given to the chemical and biological study of paddy soils. In paddy-growing countries, however, scientific workers have devoted some time and attention to the subject. Of the more important earlier investigations, reference must be made to the work of Nagaoka (1), Daikuhara and Imaseki (2), Kelley (3, 4, 5,) and Harrison and Aiyer (6, 7,) on the subject. As early as 1905, Nagaoka conducted a number of pot experiments with paddy and found that sulphate of ammonia was superior to nitrate of soda as a fertiliser for this crop in the ratio of 100 to 40. The plants manured with nitrate of soda developed chlorosis. Daikuhara and Imaseki attributed this to the reduction of nitrate to nitrite under anaerobic conditions, especially in the presence of large quantities of organic matter. They found that reduction took place in a comparatively short period of time which varied with the nature of the soil. These investigators demonstrated also that sulphate of ammonia was much more effective as a manure for rice than nitrate of soda. They attributed the unsuitability of nitrate for paddy to (1) the loss of nitrogen by denitrification and through leaching and (2) the formation of poisonous nitrites. They also furnished evidence to prove that the reduction of nitrates in paddy fields was brought about by denitrifying organisms. Kelley confirmed from field trials the conclusions of the two previous workers regarding the comparative merits of nitrate of soda and sulphate of ammonia as fertilisers for paddy, and supported the view that denitrification and the formation of poisonous nitrites were responsible for the poor results obtained with nitrate of soda. He found that when nitrites were present to the extent of more than five parts per million, the plants developed chlorosis. He also showed that on the application of nitrogenous cakes, blood meal, etc., to submerged soils large quantities of ammonia and small amounts of nitrates were produced. As a result of his experiments, Kelley recommended that rice land should not be ploughed and then allowed to lie fallow between crops, as the nitrate formed thereby would be lost when the land was subsequently irrigated. This is an important point which will be discussed later in connection with the time of ploughing in of green-manures.

Panganiban (8) in the Philippines found fairly large quantities of amino-nitrogen and confirmed the absence of nitrate in submerged soils treated with organic nitrogen. Trelease and

Paulino (17), also of the Philippines, confirmed the conclusions of previous workers that sulphate of ammonia was a much more efficient source of nitrogen for rice than nitrates. Willis and Carrero (9) showed that the degree of chlorosis obtained by the addition of nitrate of soda to paddy was proportional to the amount of nitrate added; no chlorosis was obtained with suphate of ammonia.

Harrison and Aiyer studied the question of green-manuring of paddy from the point of view of the soil gases (6, 7). In as much as they relate to this work their conclusions were that (1) the direct manurial effects of green-manures were small as a considerable amount of the nitrogen contained in the manures was liberated in the gaseous form, (2) to be directly effective green-manures should be applied at such a time and under such conditions that the nitrogen could become an integral component of the soil before the irrigation season commenced, (3) ammonia and not nitrate was the form in which nitrogen was required by rice, (4) the use of green-manures in drained paddy soils induced a greater activity on the part of the surface film which was the chief agent in causing aeration of the roots of the crop. Their work in some of its aspects will be referred to again.

More recently quantitative studies on the decomposition of green-manures in rice soils were made by Janssen and Metzger (15, 16). They studied the nitrate, nitrite and ammonia changes in submerged soils treated with green-manures and other nitrogenous fertilisers and found large increases of ammonia but only traces of nitrate and nitrite in the soils. Added nitrates were entirely lost during a period of two months. They showed that paddy manured with nitrate of soda developed chlorosis, but they attributed this to a lack of available nitrogen in the form of ammonia.

Subrahmanyan (11) showed that, when paddy soils were water-logged in the absence of freshly-decomposing organic matter, there was a distinct increase in the free and saline ammonia contents of the soils, even when the latter were treated with disinfectants. The amounts of ammonia found in the surface water were very small. Subrahmanyan therefore concluded that the formation of ammonia under these conditions was probably due to a deaminase or enzyme and not to biological action. His experiments also indicated that ammonia was present in the soil as an exchangeable base. McLean and Robinson (10) based their method for the determination of ammonia in soils on this fact.

INVESTIGATIONAL AND ANALYTICAL METHODS.

As already stated the investigation comprised both laboratory and field experiments. Two main series of laboratory experiments and a third series of supplementary experiments set up in order to elucidate some points arising from the two primary series

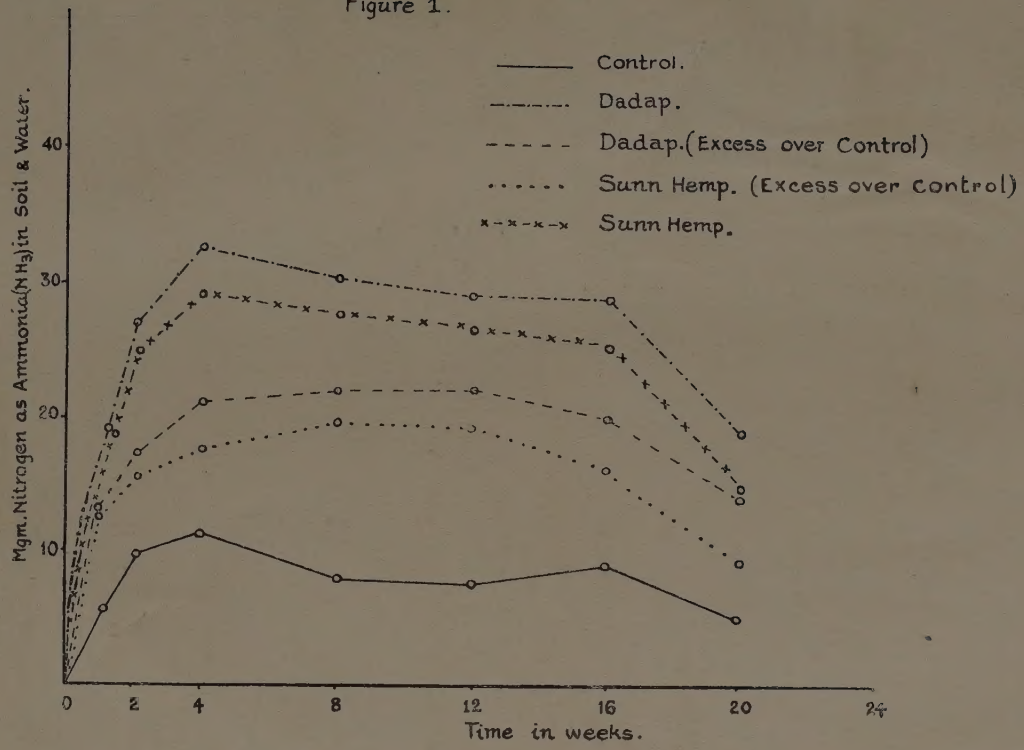
were carried out. Two field experiments were undertaken in co-operation with the Economic Botanist. The underlying theme of these experiments was the study of the nitrogen changes in the soil as a result of green-manuring. Determinations of total nitrogen, ammonia, nitrate and nitrite at various stages of the progress of both field and laboratory experiments were therefore made. The details of the methods will be described when each series is being dealt with. The analytical methods adopted were as follows: total nitrogen by the Kjeldahl method modified to include nitrate nitrogen when necessary; nitrates by the modified phenol-disulphonic acid method; nitrites by the Greiss-Illosvay colorimetric method; ammonia by the recent McLean and Robinson method.

LABORATORY EXPERIMENTS.

SERIES I.

These experiments were designed to study the chemical changes occurring in submerged soils as a result of green-manuring and to ascertain in what way green-manuring under submerged conditions affected soil fertility. They were started on the 27th April and completed on the 26th September, 1928. The experiments were carried out as follows: Soil from the paddy plots at the Farm School, Peradeniya, was air-dried and sieved through a 3 mm. sieve. Forty-two lots each of 300 gm. of soil were weighed out. Fourteen lots were mixed with 3 gm. each of the leaves and tender stems of sunnhemp (*Crotalaria juncea*), a green-manure commonly used for paddy, another fourteen with the leaves and tender stems of dadap (*Erythrina lithosperma*), and the remainder were left as controls. The sample of sunnhemp used was rather fibrous. The amount of green material added was equivalent to about 10 tons per acre to a depth of six inches of soil. The nitrogen contents of the green-manure materials and of the soil were determined at the start. The lots were put into wide-mouthed bottles, about 150 cc. of water was added to each, and the soils were well mixed. A further 150 cc. of water was added later, making 300 cc. in all, and the soils were thoroughly puddled. The excess of water remained on the surface of the puddled soil. The bottles were then weighed and loosely covered over with watch glasses. At the end of one, two, four, eight, twelve, sixteen and twenty weeks, the soil and supernatant liquid of two bottles of each set of pots were separately analysed for nitrates, nitrities and ammonia. The bottles were weighed from time to time and water was added to them to maintain the original water content. Observations of the changes occurring in the pots were made periodically. In about a week's time obnoxious smells due to the decomposition products of the green materials formed under anaerobic conditions were emitted. These gradually disappeared and were followed a week or so later

Figure 1.


Control.
Dadap.
Dadap.(Excess over Control)
Sunn Hemp. (Excess over Control)
Sunn Hemp.
Mgm. Nitrogen as Ammonia(NH_3) in Soil & Water.
40
30
20
10
0
2
4
8
12
16
20
24
Time in weeks.

by a distinct rise in level of the water in the green-manured pots. The gaseous space in the soils in these pots as well as the amount of filmy material on the surface of the soil and water had increased considerably. Appreciable quantities of gases were also given out. No such changes were observed in the control pots. The observations of Harrison and Aiyer (6, 7) were therefore confirmed. Increased aeration of the roots of the paddy plant is therefore an important indirect advantage of green-manuring.

The results of the ammonia determinations of the soils and supernatant liquids are shown in tables I, II and III below. Table I shows the amounts of nitrogen as ammonia in 100 gm. soil at 100°C and in the total amount of soil. Table II shows the amounts of nitrogen as ammonia in the supernatant liquid, and Table III the total ammonia in the soil plus liquid. Table III also shows the period of maximum ammonification and the percentages of nitrogen ammonified. Figure 1 shows graphically the changes in the ammonia contents of the pots. In the tables only the mean data are quoted. No traces of nitrate were found at any stage of the decomposition process. Nitrites were found in traces at the end of the first week and not afterwards. These results were in accordance with those of other workers on the subject (4, 5, 15, 16).

Table I.

Mgms. of nitrogen as ammonia in total amount of soil.
Mgms. of nitrogen as ammonia in 100 gms of soil at 100°C.

Time of sampling in weeks.	1	2	4	8	12	16	20
Control.	5·3	9·3	11·0	7·8	7·2	8·7	4·9
	2·0	*3·3*	*3·9*	*2·8*	*2·6*	*3·1*	*1·7*
Dadap.	17·5	24·8	29·6	28·6	29·0	28·3	18·7
	6·2	*8·9*	*10·7*	*10·2*	*10·4*	*10·1*	*6·7*
Sunnhemp.	17·0	22·9	26·3	26·7	25·6	24·9	14·2
	6·1	*8·2*	*9·4*	*9·7*	*9·2*	*8·9*	*5·1*

Table II.

Mgms. of nitrogen as ammonia in total amount of liquid.
Mgms. of nitrogen as ammonia in 100 c.c. of liquid.

Time of sampling in weeks.	1	2	4	8	12	16	20
Control.	·70	·37	·37	·29	·29	·26	·17
	·56	*·29*	*·31*	*·26*	*·30*	*·29*	*·21*
Dadap.	1·77	2·34	2·43	1·54	·89	·68	·33
	1·32	*2·23*	*2·08*	*1·30*	*·94*	*·72*	*·36*
Sunnhemp.	1·83	1·88	2·70	1·08	·80	·33	·21
	1·40	*1·92*	*2·59*	*1·01*	*·80*	*·38*	*·25*

Table III.

Mgms. of nitrogen as ammonia in soil and liquid.
Mgms. of nitrogen as ammonia (increase over control).

Time of sampling in weeks.	1	2	4	8	12	16	20	Mgms. nitrogen added as green manure	Period of maximun ammoni-fication in weeks	Maximum percentage ammoni-fied
Control.	6.0	9.67	11.37	8.09	7.49	8.96	5.07	—	4	—
Dadap.	19.27 *13.27*	27.14 *17.47*	32.02 *20.65*	30.14 *22 05*	29.89 *22.40*	28.98 *20.02*	19.30 *19 36*	23.74	4-8	92.1
Sunnhemp.	18.83 *12.83*	24.78 *15.11*	29.00 *17.63*	27.78 *19.69*	26.40 *18.91*	25.23 *16.27*	14.41 *9.34*	30.40	4-8	64.9

In addition to the determinations of ammonia, nitrate and nitrite at regular intervals, total nitrogen determinations of the soils at the start and at the conclusion of the experiment and of the green materials added were made in order to study the nitrogen balance in the soil. The results are shown in table IV.

Table IV.

	Initial nitrogen in soil at 100°C		Nitrogen in green manure added		Final nitrogen in soil at 100°C.		Net loss or gain in soil nitrogen		Total loss or gain in nitrogen.
	%	Mgms.	%	Mgms.	%	Mgms.	%	Mgms.	Mgms.
Control.	.1188	332.6	—	—	.1060	296.8	—10 7	—35.8	—35.8
Dadap.	.1188	332.6	.7914	23.7	.1198	335.4	+ 0.9	+ 2.8	—20.9
Sunn-hemp	.1188	332.6	1.01	30.4	.1141	319.5	— 3.9	—13.1	—43.5

DISCUSSION OF RESULTS.

A glance at tables I to III shows that (1) large quantities of ammonia were formed as a result of submerging paddy soils containing fixed organic matter. The quantities were considerably increased when green manures were added. Thus the maximum increases in ammonia of the green-manured pots over the controls were no less than 20 and 22 mgm. per 100 gm. of dry soil respectively. As 1 mgm. of nitrogen per 100 gm. dry soil is equivalent to about 25 lbs. per acre,the increase in nitrogen as ammonia due to the green manures will therefore amount to about 175 lbs. per acre; (2) by far the greater part of the ammonia was found in the soil, and, as shown by Subrahmanayan (11), only small amounts were present in the supernatant liquid but appreciable amounts were found in the supernatant liquid of the green-manured pots in the early stages; (3) the largest amounts of ammonia were found in all cases at the end of four weeks from the date of puddling, but maximum ammonification as measured by increase over the control was obtained in eight weeks, though increases near the maximum were found at the end of four weeks. After this period the ammonia contents remained more or less.

constant for about two months, after which they began to fall. Large quantities of ammonia, however, were found a week after puddling. The dadap pots generally showed higher ammonia contents than the sunnhemp pots, though the amounts of nitrogen added as green-manure were less in the case of the former. This was due to the fibrous nature of the sample of sunnhemp added. The maximum percentage of ammonification of nitrogen in the case of dadaps was 93·1 and of sunnhemp 64·9. This indicated that it is not advisable to use fibrous nitrogenous materials for green manuring paddy.

Table IV shows the nitrogen balance of the experiment. It will be noted that, as a result of maintaining soils rich in organic matter under paddy-land (anaerobic) conditions for a period of four to five months, appreciably large losses of their total nitrogen contents may occur. Thus in these experiments the control soils lost over 10 per cent. of their nitrogen. When green-manures were added, the net soil nitrogen losses were much less, due to the nitrogen contributed by the former. In the case of the dadap pots, there was even a small net gain in nitrogen. The loss of 4 per cent. of the original soil nitrogen in the sunnhemp pots was probably due to the fibrous nature of the green-manure which encourages denitrification.

All previous investigations have shown that ammoniacal nitrogen is the form of nitrogen most suitable to wet-land paddy. Kelley has also shown that paddy requires its nitrogen in the early stages of its growth (3). The results of these experiments, that soils treated with green manures and submerged under water have much larger quantities of ammonia at all stages of the decomposition process and more total nitrogen at the end of the investigation than the controls, clearly indicate therefore that green manures are of *direct* manurial value to paddy in spite of losses of nitrogen from the green-manures added. These experiments do not therefore appear to bear out Harrison and Aiyer's contents (7) that the direct manurial value of green-manures for paddy is small under *all* conditions owing to the liberation in the gaseous form of a considerable amount of the nitrogen contained in them. The experiments to be described under series II, however, will indicate that under certain conditions the direct value of green-manures is small.

SERIES II.

The object of this series of experiments was to compare the chemical changes taking place in soils when green-manures were incorporated under optimum moisture conditions for nitrification, i.e., aerobically, and were puddled six weeks later with those occurring when green-manures were buried at the time of puddling the soil, i.e., under anaerobic conditions. In short the experiment was intended to throw light on the field practices of *early* and *late* green-manuring of paddy. The paddy soil used

was the same as that in the previous series of experiments. To eighteen pots each containing 300 gm. dry soil water was added to bring the moisture content to that required for optimum nitrification, viz., half-saturation. Nine pots were mixed with 3 gm. portions of green-manure (dadap) and nine were left as controls. The pots were sampled every fortnight for six weeks and the moisture, nitrate, nitrite and ammonia contents of the soils were determined at each sampling. At the end of six weeks, the remaining pots were puddled as in series I and determinations were made of the ammonia, nitrate and nitrite contents of the soils and liquids at the end of three days and one, two, four, eight and twelve weeks after puddling. At the same time twelve other pots were treated as in the first experiment, i.e., the green manures were mixed with the soil at the time of puddling and analyses of the soils and liquids were made at the end of the same periods as in the case of the *early* green-manured pots. In both cases the muddy soils and the supernatant liquids were analysed. The methods of analysis were the same as before. The experiment was started on the 14th July and completed on the 17th November, 1928.

The results are shown in tables V, VI, VII and VIII. The amounts of nitrates found are shown in italics.

Table V.

Mgms. of nitrogen as ammonia in 100 gms. of soil at 100°C.
Mgms. of nitrogen as nitrate in 100 gms. of soil at 100°C.

	Before Puddling.			After Puddling.					
Time of sampling in weeks.	2	4	6	½	1	2	4	8	12
Control, *early*.	3·67 *3·52*	3·03 *4·15*	·77 *4·32*	·50 *2·67*	·52 *2·45*	·82 *nil*	·74 *nil*	·74 *nil*	·73 *nil*
Control, *late*.				2·63 *nil*	3·98 *nil*	4·16 *nil*	3·94 *nil*	3·65 *nil*	3·63 *nil*
Green-manure, *early*.	4·62 *3·99*	7·96 *7·64*	1·00 *9·32*	·54 *4·53*	1·34 *4·03*	1·02 *2·21*	1·17 *nil*	1·18 *nil*	1·24 *nil*
Green-manure, *late*.				3·01 *nil*	6·29 *nil*	7·02 *nil*	9·85 *nil*	9·71 *nil*	9·76 *nil*

Table VI.

Mgms. of nitrogen as ammonia in total liquid after puddling.
Mgms. of nitrate nitrogen in total liquid after puddling.

Time of sampling in weeks.	½	1	2	4	8	12
Control, *early*.	·19 —	·18 *3·39*	·15 *3·84*	·14 *3·4*	·12 *3·6*	·15 *trace*
Control, *late*.	·34 *nil*	·45 *nil*	·32 *nil*	·16 *nil*	·14 *nil*	·16 *nil*
Green-manure, *early*.	·22 —	·23 *5·15*	·22 *4·62*	·16 *3·94*	·16 *3·90*	·18 *trace*
Green-manure, *late*.	·76 *nil*	·76 *nil*	·40 *nil*	·46 *nil*	·22 *nil*	·18 *nil*

Table VII.

Mgms. of nitrogen as ammonia in total amount of soil.
Mgms. of nitrogen as nitrate in total amount of soil.

Before Puddling.				After Puddling.					
Time of sampling, in weeks.	2	4	6	½	1	2	4	8	12
Control *early.*	10·28 *9·85*	8·48 *11·62*	2·16 *12·10*	1·40 *7·47*	1·46 *6·86*	2·30 *nil*	2·07 *nil*	2·07 *nil*	2·05 *nil*
Control, *late*				7·37 *nil*	11·14 *nil*	11·65 *nil*	11·03 *nil*	10·22 *nil*	10·17 *nil*
Green-manure, *early.*	12·93 *11·20*	19·43 *21·41*	2 80 *26 10*	1·51 *12·71*	3·75 *13·32*	2·86 *6·23*	3 28 *nil*	3·31 *nil*	3·47 *nil*
Green-manure, *late.*				8·41 *nil*	17·58 *nil*	19·65 *nil*	27·58 *nil*	27·19 *nil*	27·33 *nil*

Table VIII.

Mgms. of nitrogen as ammonia in soil and liquid.
Mgms. of nitrogen as nitrate in soil and liquid.

Before puddling.				After puddling.								
Time of sampling in weeks.	2	4	6	½	1	2	4	8	12	Mgms. nitrogen added as green manure.	Period of maximum ammonification in weeks.	Maximum percentage ammonified.
Control, *early.*	10·28 *9·85*	8·48 *11·60*	2.16 *12.11*	1·59 *—*	1·64 *10·25*	2·45 *3·84*	2·21 *3·62*	2·19 *3·41*	2·20 *trace*	—	2	—
Control, *late.*				7·71 *nil*	11·59 *nil*	11·97 *nil*	11·19 *nil*	10·36 *nil*	10·33 *nil*	—	2	—
Green-manure, *early.*	12·91 *11·24*	19·51 *21·41*	2·82 *26·12*	1·73 *—*	3·98 *16·45*	3·08 *10·81*	3·44 *3·94*	3·47 *3·90*	3·65 *trace*	25·42	4	5·0
Green-manure, *late.*				9·17 *nil*	18·34 *nil*	20·05 *nil*	28·04 *nil*	27·41 *nil*	27·51 *nil*	25·95	4	65.7

DISCUSSION OF RESULTS.

An examination of the tables shows that (1) large quantities of ammonia and nitrate were found in the initial stages in the *early* green-manure and control soils. The ammonia contents fell to a minimum and the nitrates rose to a maximum at the end of six weeks; (2) on puddling, there was a slight fall in ammonia and a large fall in nitrate in the soils of both control and green-manure *early* pots. A large proportion of the soil nitrate, however, was found in the supernatant liquid which contains only small amounts of ammonia. In normal field practice the nitrates found in the surface water are lost in drainage. The nitrate in the soil was lost through denitrification in about two weeks, but that in the liquid remained for a longer time, viz., up to eight weeks, as

table VI will show. The results confirmed those of Kelley, Subrahmanyan and others (4, 5, 11). Nitrites were found in small quantities soon after puddling, but neither in soils nor liquids after the first fortnight. They were denitrified more quickly in the soils. Neither nitrates nor nitrites were found at any time in the green-manure *late* pots. The ammonia content of the supernatant liquid remained almost constant; (3) the amounts of ammonia found in the *early* control and green-manure pots were much smaller than those in the corresponding *late* pots, but the differences between the ammonia contents of the *early* control and green-manure pots were small. The advantages of burying green-manures *late* in irrigated paddy soils as regards the ammonia contents were therefore evident. If confirmation of these increases can be obtained in the field, higher yields from fields green-manured *late* than from those green-manured *early* can be expected. From the chemical standpoint, therefore, the burying of green-manures *late*, i.e., under anaerobic conditions at the time of puddling the soil, is preferable to doing so under dry or semi-dry conditions and subsequently puddling with water. The reason for this, as the data will show, is that under semi-dry conditions nitrates are formed in large quantities when paddy soils are ploughed or green-manured; these nitrates on the subsequent submergence of the fields under water are quickly denitrified, reduced to nitrites or lost in drainage. The data obtained are shown graphically in figures 2 and 3; (4) both *early* and *late* green-manure pots showed, as before maximum ammonification at the end of four weeks and the controls at the end of two weeks. The ammonia contents of the *late* pots remained more or less constant after this period. The maximum ammonification percentage was 65·7 in the case of the *late* pots and only 5 in the case of the *early* pots.

In table IX below are shown the changes which took place in the total nitrogen contents of the soils as a result of the treatment already described.

Table IX.

	Initial nitrogen in soil at 100°C.		Nitrogen in green-manure added.		Nitrogen in soil at 100°C. before puddling.		Loss or gain in soil nitrogen.		Nitrogen in soil at 100°C. after puddling.		Net loss or gain in soil nitrogen after puddling.		Total loss or gain in nitrogen.
	%	Mgms.	%	Mgms.	%	Mgms.	%	Mgms.	%	Mgms.	%	Mgms.	Mgms.
Control *early*	·1188	332·6	—	—	·1187	332·3	nil	nil	·1059	296·5	−10·8	−36·1	−36·1
Control *late*	·1188	332·6	—	—	—	—	—	—	·1091	305·4	−8·2	−27·2	−27·2
Green-manure, *early*	·1188	332·6	·8474	25·40	·1223	342·4	+·0037	+9·8	·1063	297·6	−10·5	−35·0	−60·4
Green-manure, *late*	·1188	332·6	·8650	25·95	—	—	—	—	·1183	331·2	−0·42	−1·4	−26·4

Figure 2.

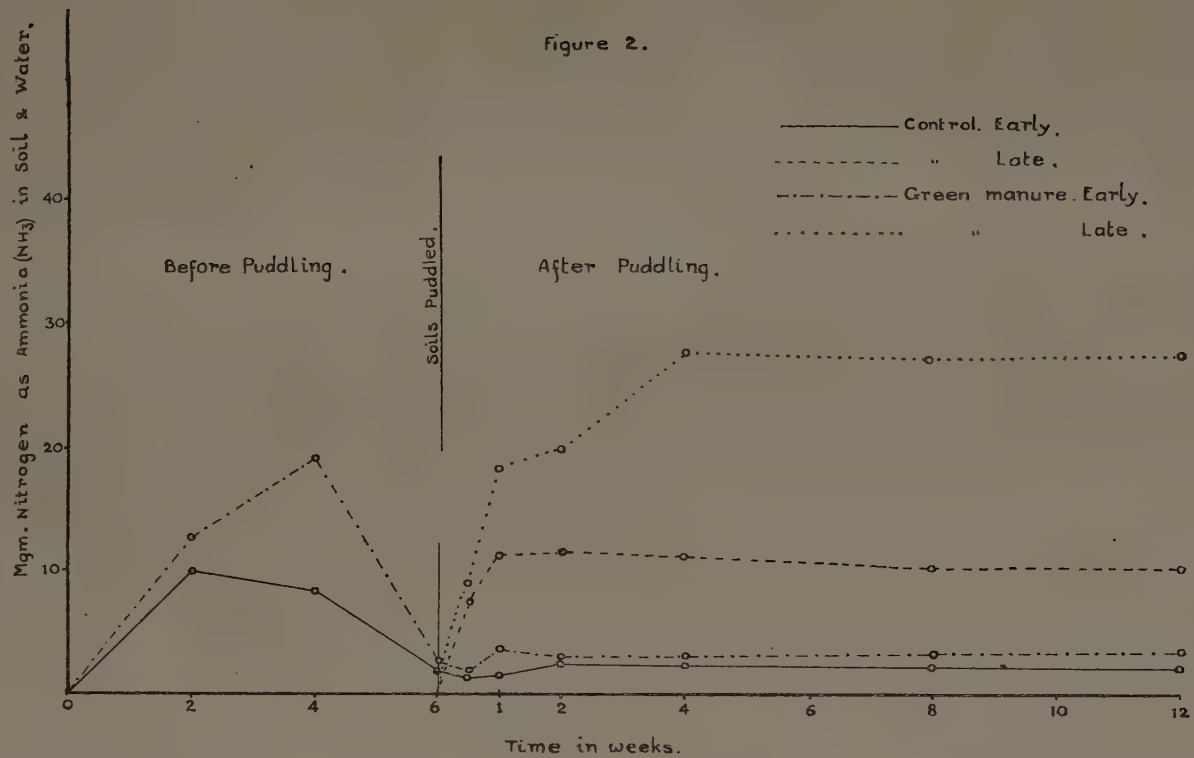
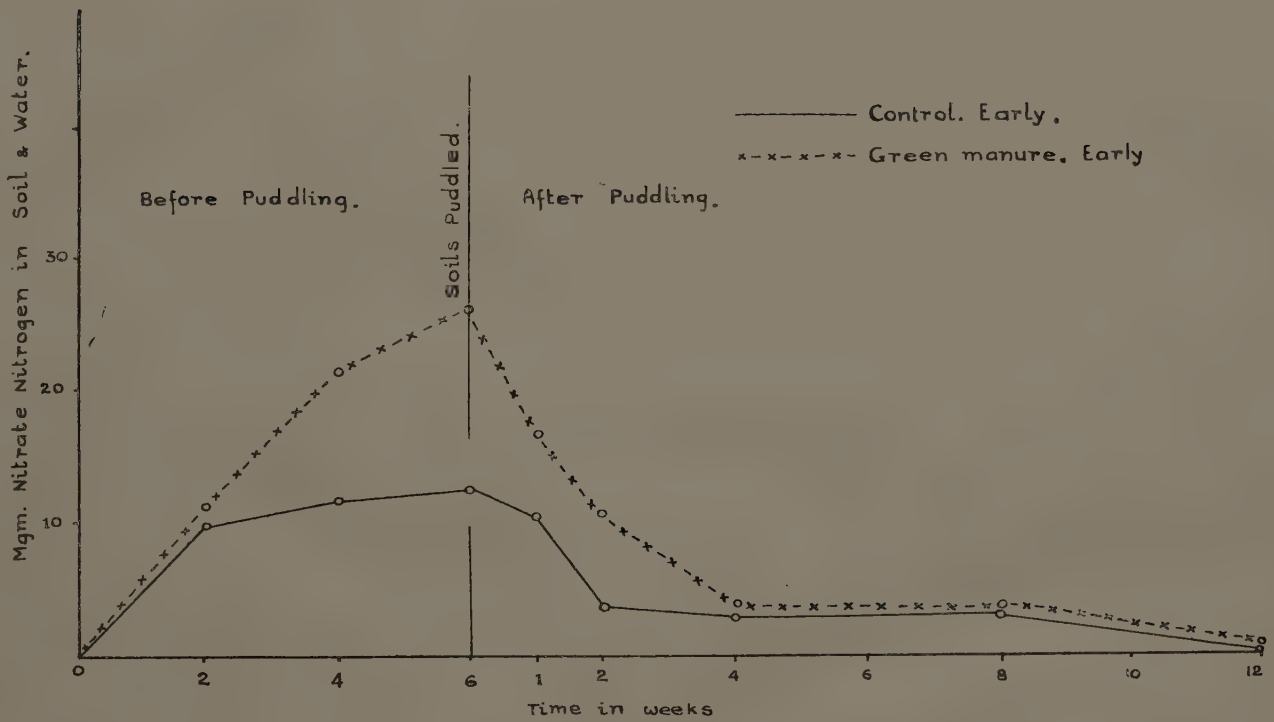

Control. Early.
" Late.
Green manure. Early.
" Late.
Before Puddling.
After Puddling.
Soils Puddled.
Mgm. Nitrogen as Ammonia (NH_3) in Soil & Water.
40
30
20
10
0
2
4
6
1
2
4
6
8
10
12
Time in weeks.

Figure 3.


Control. Early.
Green manure. Early
Before Puddling.
Soils Puddled.
After Puddling.
Mgm. Nitrate Nitrogen in Soil & Water.
30
20
10
0
2
4
6
1
2
4
6
8
10
12
Time in weeks

An examination of this table indicates that (1) as in the previous series of experiments, the total nitrogen content of the soil was maintained and might be increased by *late* green-manuring, (2) the losses of nitrogen from the *early* control pots were greater than from the corresponding *late* controls, but the losses in the latter pots were appreciable; (3) as a result of incorporating the green-manures *early* and subsequent puddling, all the nitrogen contained in the green-manure was lost, in addition to that normally lost from the soil as a result of the submergence. The advantages from the chemical standpoint of burying easily-decomposed green material in paddy fields *late* as against the practice of burying it *early* are again apparent.

SERIES III.

This series of experiments was started to elucidate certain points arising from the two previous series of laboratory experiments and the field experiments to be referred to later.

The rate of denitrification of nitrates added to water-logged soils. As the green-manure experiments of series I and II did not furnish sufficient data on the denitrification of the nitrates added to or present in soils as a result of water-logging, an experiment was set up to obtain the information required. Nitrate of soda at the rate of 100 mgm. to 200 gm. soil was added to a number of pots otherwise treated as in the previous experiments. To a number of other pots cane sugar at the rate of 100 mgm. to 100 gm. soil was added in addition to the nitrate of soda. Nitrate and nitrite determinations of the soils and liquids in the pots were made after the third day and one, two and three weeks, respectively. The results are shown in table X.

Table X.

		Nitrates (parts per million).				Nitrites (parts per million).			
Time of sampling in weeks.		½	1	2	3	½	1	2	3
With addition of sugar.	Soil	nil	nil	nil	nil	trace	trace	nil	nil
	liquid	trace	nil	nil	nil	trace	trace	nil	nil
Without addition of sugar	Soil	.45	trace	nil	nil	.40	.15	nil	nil
	liquid	19.6	11.1	1.4	trace	2.0	.30	1.5	nil

An examination of the table shows that nitrate reduction took place very quickly in the soil, especially on the addition of sugar. In the case of the pots without sugar all the soil nitrates were reduced to nitrite or leached into the liquid within a week. The nitrate in the liquid was converted to nitrite and finally lost as free nitrogen in just over two weeks. In the case of the pots to which sugar was added both nitrate and nitrite were lost within three days. These experiments therefore confirm the results of previous workers, viz., that nitrates are reduced to nitrites and

free nitrogen in soil and water under anaerobic conditions in a very short time (1, 2, 4, 5, 15), and that denitrification is greatly hastened by the presence in the soil of easily-decomposed organic matter.

Is the ammonia formed in water-logged soils through green-manuring lost on puddling? In the first field experiment to be detailed later, a marked fall in the ammonia contents of the soils was observed when fields which had previously been green-manured were puddled. The reason for the loss of ammonia was not quite apparent. To ascertain whether it was a normal occurrence, a laboratory experiment was started in which soils which had green-manures incorporated with them under optimum conditions for ammonification, as in the field, were maintained in that condition for four weeks; they were subsequently puddled and the changes taking place in the ammonia contents of the soils were determined. The data obtained are set down below.

	Ammonia in dry soil at 100°C.	
	Mgm.	Mean.
At end of four weeks.	12·77 12·49	12·63
Three days after puddling.	12·62 12·18	12·40
One week after puddling.	12·66 12·52	12·59

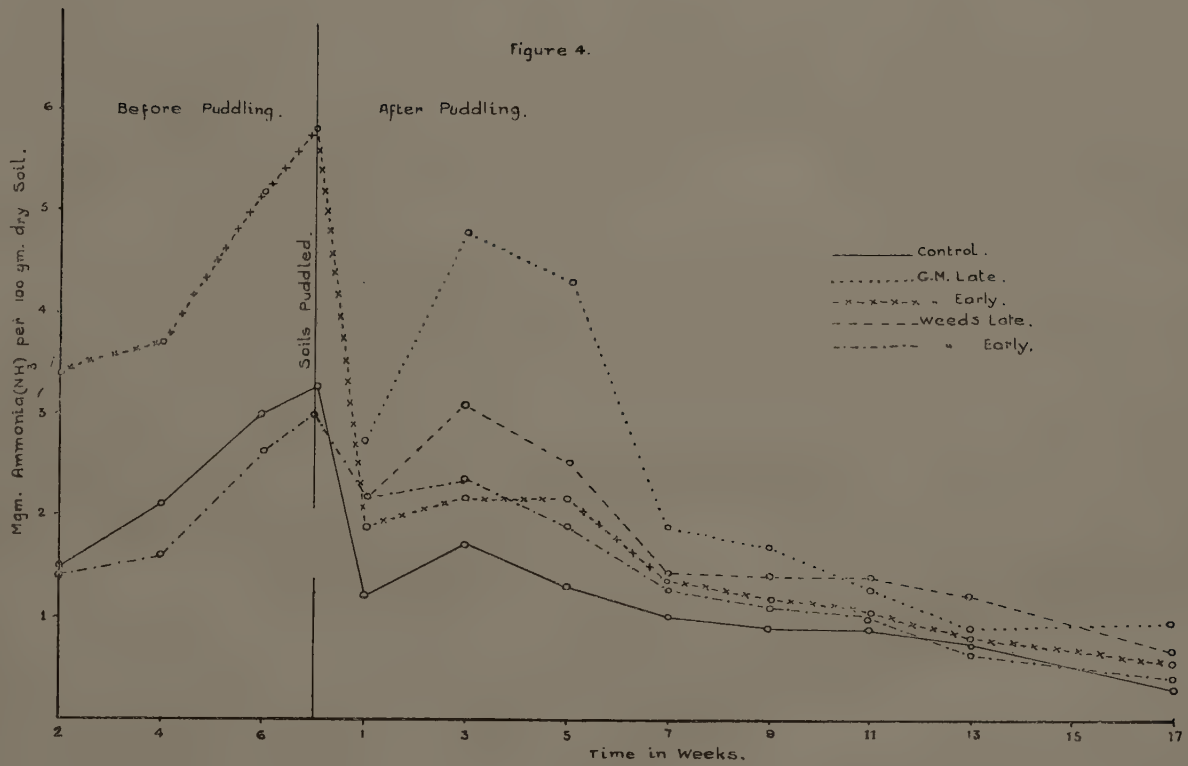
It will be noted that in this experiment the fall in ammonia content as a result of the puddling was not appreciable. This would indicate that hardly any losses of ammonia occurred from the soil through volatilization in the puddling process. The fact that no losses of ammonia occurred from soils through volatilization was also demonstrated by Subrahmanyan (11). The marked fall in soil ammonia obtained in the field experiment would therefore appear to be partly at least the result of sampling. It was likely that, as the sampling of the soils was done by hand just after puddling, a part of the clay portion of the sample which retained the ammonia was lost in the process. Some ammonia was also lost in the surface drainage. Under certain field conditions, e.g., where the fields are left to dry after being green-manured, the ammonia content of the soil just previous to puddling may be low owing to the nitrification of the ammonia formed. In these cases the ammonia contents of the soils after puddling will not be appreciably lower than before puddling. Such was probably the case in the second field experiment.

FIELD EXPERIMENTS.

SERIES I.

This experiment was started in December 1927 in co-operation with the Economic Botanist who was responsible for the carrying out of the experiment. There were twenty plots in all,

Figure 4.


Before Puddling.
After Puddling.
Soils Puddled.
Mgm. Ammonia(NH3) per 100 gm. dry Soil.
Time in Weeks.
Control.
C.M. Late.
" Early.
weeds Late.
" Early.
1
2
3
4
5
6
2
4
6
1
3
5
7
9
11
13
15
17

each of the five treatments being replicated four times in randomised blocks. The full details will be given by him in a paper to follow. The treatments were as follows: Control; weeds buried *early*; weeds buried *late*; green-manure buried *early*; green-manure buried *late*. The green-manures were grown *in situ*, and therefore no records of the weights of green material obtained were kept. In the *early* plots the green-manures were buried seven weeks and in the *late* plots one week before sowing. Soil samples from the field were taken periodically as follows: Prior to puddling two borings were taken to a depth of about six inches with an auger from each plot treated alike and these were thoroughly mixed together. After puddling, the soils were sampled by hand owing to their being muddy. Determinations of moisture, nitrate, nitrite and ammonia were made on each soil sample. Unfortunately the yields of paddy could not be obtained in this experiment owing to damage by rain. As the chemical data obtained are interesting they are set down in table XI below and graphically illustrated in figure 4.

Table XI.

Mgms. of nitrogen as ammonia in 100 gms. of soil at 100°C.
Mgms. of nitrogen as nitrate in 100 gms. of soil at 100°C.

	Before puddling.				After puddling.							
Time of sampling in weeks.	2	4	6	7	1	3	5	7	9	11	13	17
Control.	1·5 *·55*	2·1 *·96*	3·0 *·75*	3·23 —	1·22 *nil*	1·73 *nil*	1·31 *nil*	1·05 *nil*	·91 *nil*	·88 *nil*	·73 *nil*	·27 *nil*
Green-manure, *late*.					2·69 *nil*	4·79 *nil*	4·30 *nil*	1·87 *nil*	1·69 *nil*	1·30 *nil*	·87 *nil*	.96 *nil*
Green-manure, *early*.	3·4 *·37*	3·7 *·70*	5·2 *·78*	5·8 —	1·85 *nil*	2·13 *nil*	2·13 *nil*	1·36 *nil*	1·16 *nil*	1·05 *nil*	·83 *nil*	·63 *nil*
Weeds, *late*.					2·14 *nil*	3·06 *nil*	2·50 *nil*	1·41 *nil*	1·42 *nil*	1·37 *nil*	1·25 *nil*	·70 *nil*
Weeds, *early*.	1·4 *·45*	1·6 *·55*	2·7 *·45*	3·0 —	2·02 *nil*	2·36 *nil*	1·89 *nil*	1·27 *nil*	1·08 *nil*	1·04 *nil*	·63 *nil*	·44 *nil*

DISCUSSION OF RESULTS.

An examination of the data of table XI shows that (1) as in the laboratory experiments large amounts of ammonia were formed as a result of the *early* ploughing in of the green-manures. This large ammonia production was due to the soil moisture conditions during the whole period of the experiment being favourable for ammonification and unfavourable for nitrification. Only small amounts of nitrate were found; (2) on puddling the soil a very marked fall in ammonia in all the *early* plots was observed. The reason for this fall was not clear, as the laboratory experiments carried out do not show losses of ammonia due to volatiliza-

tion on puddling soils containing large quantities of ammonia. As stated previously, however, the loss of ammonia in the surface drainage and the sampling error afford a probable explanation of this observation; (3) the *late* plots, i.e., those in which the green-manures or weeds were puddled *late* showed during the whole period of the experiment much higher ammonia contents, the maximum being reached about three or four weeks after puddling. From the chemical standpoint, therefore, the field experiments confirmed the results of laboratory experiments that it was preferable to bury green material under paddy-land conditions *late* than *early*. It was unfortunate that no yield data could be obtained owing to the adverse weather conditions, but it may be stated that the *late* plots appeared superior to the *early* plots.

SERIES II.

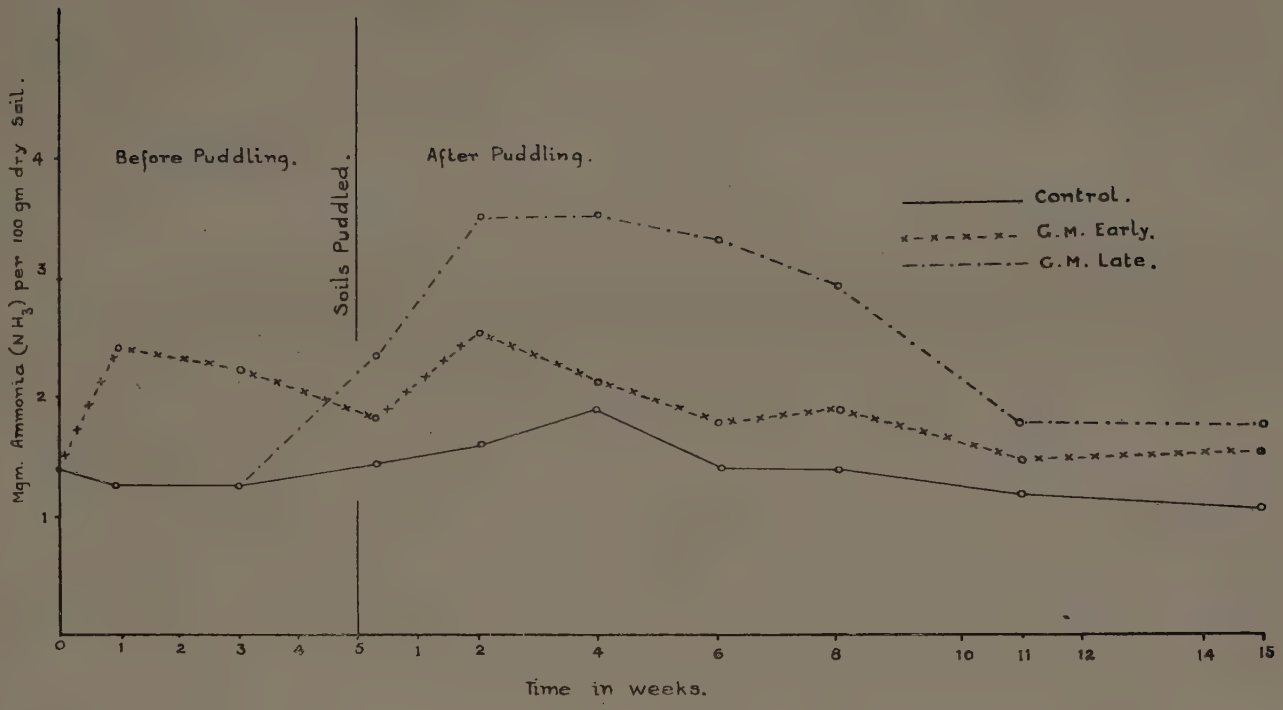
Owing to the lack of yield data in the first experiment, a second experiment to ascertain whether *early* or *late* green-manuring of paddy lands was preferable, was laid down in co-operation with the Economic Botanist. It was begun on the 27th August, 1928 and completed early in March, 1929. The *early* green-manure plots were buried five weeks and the *late* plots one week previous to transplanting. The green-manure was added in the form of wild sunflower (*Tethonia diversifolia*) loppings at the rate of five tons per acre. Representative samples of the loppings and of the soils from the plots were analysed for nitrogen at the start of the experiment and at the conclusion. Determinations of the nitrogen contents of the soils from the plots were again made. At regular intervals samples were taken for the determination of ammonia, nitrates and nitrites. As the soils were very moist, no nitrate was found at any time. Traces of nitrite were found in the early stages but these disappeared later. Duplicate samples were taken in all cases and the average figures obtained are shown in table XII. The latter are shown graphically in figure 5. It is regretted that, as no sample was taken just prior to puddling, a confirmation of the fall in ammonia on puddling the soil as in the previous experiment could not be obtained.

Table XII.

Mgms. of ammonia in 100 gms. of soil at 100°C.

Before puddling				After puddling										
Time of sampling in weeks	At start	1	3	½	2	4	6	8	11	15	Nitrogen added as green manure in lb. per acre.	Period of maximum ammonification in weeks.	Maximum percentage ammonified.
Control	1·40	1·26	1·25	1·40	1·60	1·91	1·44	1·44	1·18	1·10	—	2—4	—
Green-Manure *early*	1·44	2·39	2·17	1·81	2·48	2·06	1·80	1·91	1·52	1·65	65·5	2—4	24·9
Green-Manure *late*	1·47	1·25	1 15	2·32	3·49	3·45	3·27	2·94	1·84	1·77	65·5	2—4	53·4

Figure 5.


Mgm. Ammonia (NH_3) per 100 gm dry Soil.
4
3
2
1
Before Puddling.
Soils Puddled.
After Puddling.
Control.
G.M. Early.
G.M. Late.
0
1
2
3
4
5
1
2
4
6
8
10
11
12
14
15
Time in weeks.

DISCUSSION OF RESULTS.

An examination of the data of the table shows that the results of the first field experiments and of the laboratory experiments were confirmed. Thus (1) the ammonia contents of the soils in the *late* green-manure plots during the whole of the growing period were much greater than those in the *early* and control plots. The latter had the smallest ammonia contents at each sampling; (2) the maximum increase over the control was obtained at the end of two weeks after which the ammonia content remained constant till the sixth week and then fell. The maximum ammonification percentages obtained were 25 and 53 in the *early* and *late* green-manure plots respectively.

On the above chemical data the *late* plots may be expected to yield much better than the *early* or control pots. The yield figures of grain and straw indicate that the *late* plots gave definitely larger yields than the *early* plots and that both *early* and *late* green-manure plots were superior to the controls. The yield data will be fully dealt with by the Economic Botanist. Parnell (13) has demonstrated the efficacy of *late* green-manuring of paddy and the practice seems to be general in India (14).

In table XIII below is shown the soil nitrogen balance in the field experiment.

Table XIII.

	Initial nitrogen in soil at 100°C. %	Final nitrogen in soil at 100°C. %	Net loss or gain in nitrogen. %
Control	·1895	·1791	—·0104
Green-manure *early*	·1871	·1801	—·0070
Green-manure *late*	·1885	·1939	+ ·0054

It will be noted from the above figures that the control plots as well as the green-manure *early* plots lost soil nitrogen and that apparently the latter lost also the nitrogen added in the green-manure. The green-manure *late* plots, on the contrary, showed a small net gain in soil nitrogen. The gain in or the maintenance of the nitrogen content of the soil was obviously due to the nitrogen added in the green-manure. The results again confirm the conclusion obtained from the laboratory experiments that with regard to soil nitrogen *late* green-manuring of paddy is preferable to *early* green-manuring.

GENERAL DISCUSSION.

In the preceding pages the results are detailed of laboratory and field experiments carried out to study the nitrogen changes taking place in submerged paddy soils when green-manures are incorporated with them under varied conditions. It has been clearly demonstrated that green-manuring at the proper time and under suitable conditions, i.e., if the green-manures are incor-

porated with the soil at the time of puddling (*late*), causes a marked increase in ammonia in the green-manured soils over the controls. Neither nitrates nor nitrites were found in appreciable quantities at any stage of the decomposition process. Much larger quantities of soil gases and an increased amount of film are also produced in the *late* green-manure pots compared with the *early* green-manure and control pots. Green-manured soils are consequently much better aerated than non-green-manured soils. The indirect effects of green-manures, as pointed out by Harrison and Aiyer (7, 8), are therefore of importance if the green-manures are buried *late*.

A study of the total nitrogen changes in the *late* green-manured soils shows that the total soil nitrogen may be maintained or even slightly increased by green-manuring under these conditions and that losses of nitrogen, either more or less than the amount added in the green-manure, may occur, depending on the condition of the green material. The more woody or fibrous the latter, the more nitrogen is lost. But in all cases the control soils show much larger losses of total nitrogen. Green-manuring *late* is therefore of direct manurial value, firstly by minimising the losses of total soil nitrogen taking place under the anaerobic conditions in which paddy is grown, and secondly by increasing the ammonia contents of the soils during the entire period of the growth of the crop or the continuance of the laboratory experiments. Harrison and Aiyer's contention that green manuring is of no direct manurial value to paddy "as a considerable amount of the nitrogen contained in green-manures is liberated in the gaseous form and so made useless so far as the feeding of the crop is concerned" does not therefore apply in all cases.

It does however apply in the case of green-manures applied *early*, i.e., ploughed in when the soil is more or less dry and subsequently puddled. Both field and laboratory experiments have shown that under such conditions much smaller quantities of ammonia are formed in the soil after puddling and that the total losses of soil nitrogen are as great as in the controls. A large proportion of the nitrogen added in the green-manure may also be lost. These observations are easily explained. When green-manures are ploughed in *early* they decompose producing large quantities of nitrates in addition to ammonia as the conditions are generally favourable for nitrification. On the subsequent puddling of the soils the nitrates formed are leached in the drainage water and are lost as free nitrogen or reduced to nitrites which in excess are harmful to young paddy. Hence little nitrogen remains for further ammonification.

The field experiments show definitely that by green-manuring increased yields of grain and straw can be obtained and that higher yields can be obtained by *late* than by *early* green-manuring.

Both laboratory and field experiments have an important bearing on field practice. It is evident from a study of the results that, in general, paddy land should not be ploughed or green-manured immediately a crop is taken and then allowed to lie fallow, as nitrification will set in and, on subsequent puddling before sowing, all the nitrates formed either from the soil organic matter or from the green-manures added will be lost to the crop or reduced to injurious nitrites. The above conclusion was also arrived at by Kelley (5). It therefore appears necessary in *early* ploughing to let in water immediately afterwards. Nitrate formation will thereby be prevented and ammonia production will be encouraged. Unlike the nitrates the soil ammonia is not lost on the subsequent puddling of the soils.

The same practice should be adopted in the case of green-manures grown *in situ*. If they have to be ploughed in *early*, water should be let in immediately after in order to prevent nitrification. Where green-manures are brought from outside, ploughing them in as *late* as possible before sowing the crop and under soil conditions as moist as possible is recommended. In general, about two weeks before the crop is planted may be considered sufficiently *late* for ploughing in green-manures, provided the fields are kept subsequently under water. Care must however be taken to see that the fields are well drained or the toxic decomposition products formed may have harmful effects on the paddy seedlings.

SUMMARY.

Laboratory and field experiments were undertaken to study the chemical changes taking place in soils green-manured under paddy land conditions, to ascertain the optimum time and conditions for ploughing in the green-manures, e.g., whether *early* or *late* burial is preferable, and to determine the magnitude of the yields obtained.

The experiments have demonstrated the following.

(1) As a result of incorporating green-manures in paddy soils at the time of puddling, i.e., *late*, large quantities of ammonia are made available to the soils at all stages of the decomposition process or of the crop growth. Maximum ammonification is obtained in about four weeks from the time of puddling, in both field and laboratory experiments. In the laboratory experiments the amounts of ammonia formed remain constant for about four months and then fall slightly. In the field the soil ammonia content begins to fall after about the sixth or seventh week. As paddy takes up its nitrogen in the form of ammonia and requires it during the early stages of its growth, the direct advantages of green-manuring paddy under suitable conditions are therefore apparent.

(2) By *early* green-manuring, i.e., the ploughing in of green-manures when the soil is semi-dry, large quantities of nitrates are formed. On the subsequent flooding and puddling of the soil these are either lost as free nitrogen, leached in the drainage water or reduced to nitrites which are injurious to paddy seedlings if present in excess. The amounts of ammonia found in *early* green-manured soils after puddling are only slightly greater than those present in the controls and very much less than those found in the corresponding *late* green-manured soils.

(3) Determinations of the total nitrogen of the soils at the end and at the beginning of the experiments have shown that in the case of both laboratory and field experiments the total nitrogen content of the soils can be maintained or even increased by *late* green-manuring. Large losses of total soil nitrogen occur from the controls and from the *early* green-manured soils. The losses of nitrogen from the green-manured soils are the greater the more fibrous the material buried. The use of easily-decomposed green material is therefore recommended in paddy cultivation.

(4) The indirect effects of green-manuring in increasing the surface film and hence the aeration of paddy soils and of the roots of the crop, as pointed out by Harrison and Aiyer (6, 7) are appreciable, provided the green-manure is buried *late*.

(5) No nitrates are found in paddy soils after they have been puddled. Any nitrates present or added before puddling are quickly denitrified or converted into nitrites. Denitrification is encouraged by the presence of easily-decomposed organic matter in the soil.

(6) From the above it will be obvious that, from the chemical standpoint, the burial of green-manures in paddy fields as *late* as possible before sowing or transplanting the crop is preferable to burying *early*. This conclusion is confirmed by the field experiments which show that appreciable increases in yields of grain and straw are obtained by the *late* application of green-manures.

(7) Paddy fields should not generally be ploughed and then allowed to lie fallow, if paddy is grown wholly under submerged conditions. Otherwise the nitrates formed will be lost on the subsequent flooding and puddling of the fields prior to sowing or transplanting. If *early* ploughing has to be done, water should be let in immediately after, to keep the soil quite moist. Ammonia production which is beneficial to wet-land paddy is thereby encouraged and the ammonia formed is not lost to the soil and to the crop on subsequent flooding. When water is not available, it is better to leave the land unploughed till just before the preparation for the next crop. These recommendations are in accordance with those of Kelley (5).

(8) Where green-manures are grown *in situ*, they should not be ploughed in and then allowed to decompose under dry-land conditions for reasons already explained. After the ploughing, the fields should be flooded and the soils kept quite moist. When green-manures are brought in from outside, they should be incorporated into the soil as *late* as possible before sowing or transplanting the crop, and the fields should not be allowed to dry in the interval. Great care should be taken to see that the fields are well-drained, or the toxic decomposition products of the buried green material formed during the early stages of the process may prove injurious to the paddy seedlings.

(9) From the results of experiments recorded above and for reasons explained, it will be evident that in manuring wet-land paddy with artificial fertilizers, nitrogen should not be applied in the form of nitrates but in the form of ammonia, e.g., sulphate of ammonia, cyanamide or ammophos. This recommendation has been made by Nagaoka (1), Kelley (4, 5), Harrison and Aiyer (6, 7) and others.

ACKNOWLEDGMENT.

The writers acknowlege with thanks the assistance rendered them by Mr. G. L. de Silva in preparing the diagrams.

REFERENCES.

1. Nagaoka.—On the Behaviour of the Rice Plant to Nitrates and Ammonium Salts. *Bul. Col. Agr. Tokyo.* Vol. VI. 1905.
2. Daikuhara and Imaseki.—On the Behaviour of Nitrates in Paddy Soils. *Bul. Imp. Agr. Expt. Stn. Japan.* Vol. I. No. 2. Oct., 1907.
3. Kelley and Thompson.—A Study of the Composition of the Rice Plant. *Hawii. Agr. Expt. Stn.* Bul. No. 21. Apr., 1910.
4. Kelley.—The Assimilation of Nitrogen by Rice. *Hawii Agr. Expt. Stn.* Bul. No. 24. June, 1911.
5. Kelley.—Rice Soils of Hawii. *Hawii Agr. Expt. Stn.* Bul. No. 31. Jan., 1914.
6. Harrison and Aiyer.—The Gases of Swamp Rice Soils; their Composition and Relationship to the Crop. Parts 1 and 2. *Mem. Dept. Agr. India. Chem. Series.* Vol. III. 1914.
7. Harrison and Aiyer.—The Gases of Swamp Rice Soils. Part 4. *Mem. Dept. Agr. India. Chem. Series.* Vol. V. Jan., 1916.
8. Panganiban.—Rate of Decomposition of Organic Nitrogen in Rice Paddy Soils. *Phil. Agric.* Vol. XII. No. 2. July, 1923.
9. Willis and Carrero.—Influence of Some Nitrogenous Fertilisers on the Development of Chlorosis in Rice. *Jour. Agr. Res.* Vol. XXIV. May, 1928
10. Mc Lean and Robinson.—A New Method for the Determination of Ammoniacal Nitrogen in Soils. *Jour. Agr. Sc.* Vol. XIV. Apr., 1924.
11. Subrahmanyan.—Bio-Chemistry of Water-logged Soils. *Jour. Agr. Sc.* Vol. XVII. Parts 1 and 2. June, 1927.
12. Molegode.—Green Manure for Paddy. *Trop. Agric.* Vol. LXVI. March, 1926.
13. Parnell.—Green Leaf Manuring of Dry Land Paddy. *Year Book. Madras. Agr. Dept.* 1919.
14. Lord.—Paddy Notes (2 b). An Account of Two Cultural Experiments. Green Manuring Experiment. *Trop. Agric.* Vol. LXIX. Dec., 1927.
15. Janssen and Metzger.—Transformation of Nitrogen in Rice Soils. *Jour. Amer. Soc. Agron.* Vol. XX. No. 5. May, 1928.
16. Metzger and Janssen.—The Relation of Sodium Nitrate and Certain Other Nitrogen Carriers to the Development of Chlorosis in Rice. *Jour. Agr. Res.* Vol. XXXVII. No. 10. Nov., 1928.
17. Trelease and Paulino.—The Effect on the Growth of Rice on the Addition of Ammonium Nitrate Salts in Soil Cultures. *Phil. Agric.* Vol. VIII. No. 8-9. May, 1920.

THE CONTROL OF BLACK BEETLE (ORYCTES RHINOCEROS L.) IN COCONUT PALMS.

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THE coconut palm in Ceylon is subject to the depredations of the rhinoceros or black beetle (*Oryctes rhinoceros* L.). The pest is widely prevalent though not commonly serious, but in young palms in particular the damage to the crown may result in considerable retardation in growth. In severe attacks much of the crown is destroyed and in rainy weather a decay of the bud tissues sets in which leads eventually to the death of the plant. With the decay of the bud the red weevil (*Rhyncophorus ferrugineus* F.), a more destructive pest of the palm, may be attracted to the crown, but the normal damage caused by black beetle in the crown is seldom followed by the entry of red weevil.

The attacks of black beetle are confined to the crowns of healthy palms of all ages, the beetle stage only being involved. Red weevil, on the other hand, centres its attention on the stems of young palms to which it gains an entry generally by laying its eggs in wounds or cracks in the stem or leaf bases. Black beetle enters the crown through the leaf sheaths and bores its way into the tissues of the immature leaves and stalks enveloping the central bud, but it rarely reaches the central bud itself. The beetles feed on the sap issuing from the wounded tissues and migrate elsewhere for purposes of breeding. The damage to the leaves is seen after they unfold; it consists of the characteristic notches and serrations on the leaflets while on the leaf bases irregular holes and scars may be noticed. The presence of a beetle within the crown may be detected by the protrusion, easily seen in a young palm, of pieces of fibre from the bases of the younger leaves.

Breeding does not take place in the living palm but occurs in a wide variety of sites such as rubbish heaps, organic manure piles and rotting portions of plants. The presence of moist, decaying vegetable matter is necessary as food for the developing grubs

but the amount of food required may be quite inappreciable as the grubs have been found to subsist in the loose earth of supply holes.

In the control of this pest, the measures resorted to are directed against the beetles in the palm and the grubs in their breeding sites. The collection of the beetles while feeding in the crowns is carried out by means of a probe inserted between the stalks of the unfolded leaves enveloping the crown. The probe may comprise a flexible rod or wire with a barbed end on which the intruding beetle is impaled. After extraction, the hole, made by the beetle and often enlarged by the use of the probe unless a considerable degree of skill is exercised in its use, is plugged with such material as a mixture of sand and tar. This is necessary to prevent the entry of other organisms and the incidence of decay following the penetration of rain. The method requires the individual treatment of attacked trees and in general only a single beetle can be removed from the crown of each infested tree. On an extended scale the method applicable to the young palm thus has the disadvantage of being laborious and expensive. In addition it offers no satisfactory control if breeding is allowed to continue unchecked in the vicinity.

Attention to the grubs in their breeding sites offers greater possibilities of control. Elimination of the common breeding sites will effect a considerable diminution in the incidence of the pest and general sanitation is of vital importance in this connection. Collections of decaying vegetable refuse which provide an attractive substratum for developing grubs require suitable disposal which depends to a large extent on the nature of the material, the soil, and other conditions.

With easily decomposable plant residues such as leaves and succulent stems in which cellulose is the chief constituent, the practice of burying accumulations is preferable to burning as it provides on decomposition a valuable food supply for plant growth. Burying should be carried out at a reasonable depth with a cover of several inches of soil to prevent egg-laying beetles finding their way below. The forking in of such material to ensure sparse and even admixture with the soil may also be carried out with advantage. The incorporation of vegetable matter with the soil is not always advisable and should only be carried out where conditions are favourable to the activity of the soil micro-organisms which are responsible for the decomposition changes that take place in plant residues. On heavy undrained land the burying of vegetable matter may lead to harmful results and toxic compounds may be liberated.

The burying of woody material and other parts of plants in which lignin is predominant is of little value as decomposition is slow and its products are not rendered readily available to the growing plant. It is more advantageous to burn such material and to use the ash as a source of potash for the plant. Such woody material as rotting stumps and logs affords excellent breeding sites for black beetle and the general prevalence of this pest in Ceylon may be ascribed in part to neglect to dispose of decaying palm stems. Breeding commences in the less mature tissues at the apex of the stem but in young palms the stem may be liable to immediate attack along its entire length. Except in dry districts the burning of coconut stems and boles is a difficult operation. Splitting of the stem from the apex downwards until the harder tissues are reached and allowing the segments to dry is sufficient protection against the presence of grubs of black beetle in the dead palm. The harder wood offers no immediate attraction to the pest and need not be dealt with until further decay takes place when it may also be split, but in young palms which have died the whole stem requires to be split. When the split parts have dried, they will no longer breed the pest but they should be burnt for their ash content. The process of splitting coconut stems and boles, however, may prove prohibitive in cost on a large scale, and, if burning is difficult, the deep burial in large pits of all dead parts should be carried out. The addition of lime will facilitate decay.

The leaf bases of the coconut palm also decay slowly and contain decomposition products which are useless for plant growth. When buried in trenches they may attract egg-laying beetles, but, as the leaf bases are easily burned, they should be severed from the leaves and destroyed. Coconut husks have proved useful as a mulch in trenches and they have not been found to harbour the grubs of black beetle.

In the selection of breeding sites, black beetle has been observed to show a marked degree of preference. This indicates the use of traps of the material preferred for breeding in and efforts to induce the beetles to lay their eggs in them. The traps should be examined at frequent intervals when the different stages of the pest may be easily collected and destroyed. In the Matara district experiments with various traps have been carried out for over two years by Mr. E. Nicollier on Charlvic Estate, Kekanadura. Traps composed of rubbish deposits, grass pits and piles, kitul (*Caryota urens* L.) stems in piles, etc., have been tested but most success has been obtained from the use of mounds of grass which are built up to a height of three or four feet and have a slight central depression to facilitate the collection and entry of rain water for keeping the mass moist. They should be examined at intervals of about ten to fourteen days and can be

used again and again until the decayed state of the grass no longer attracts the beetles. All stages of the pest can be collected in the grass heaps and the eggs which are laid in specially constructed cocoons may be found to the extent of as many as twelve in each. It is realised, however, that grass is not always available on estates but use may be made of other material. Piles of refuse are easily made and it is not difficult to keep them moist internally. Coconut logs split into two and piled up have also proved successful. If a careful examination of the traps is carried out at suitable intervals, the collections which may at first comprise all stages of the pest may later show a progressive reduction in numbers with eggs as the predominant stage. Systematic collection gives little opportunity for other stages to develop. On a large area a number of traps should be placed at different points; in this way considerable numbers of eggs and also of grubs and adults may be secured. The breeding of black beetle can thus be effectively checked and a satisfactory control of its ravages attained. The use of breeding traps would appear worthy of extensive application, particularly in young plantations where black beetle can cause serious damage.

MYCOLOGICAL NOTES (19).

A SEEDLING DISEASE OF DADAP (ERYTHRINA LITHOSPERMA BL.)

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DADAP seedlings were received in May 1928 from an estate in Hatton. The report stated: "Nursery plants about three months old. The whole nursery is apparently suffering from the same complaint, while the smaller plants are dying out. The disease seems in the first instance to take the form of a certain discoloration near or below the collar." The seedlings sent for examination were six to nine inches in height and up to three-tenths of an inch in diameter. Some of the seedlings were dead and the others appeared to have been dying at the time they were dug up. At ground level the stems were shrunken and shrivelled, straw-coloured and bordered above and below by a narrow purple-brown margin. The photograph illustrates the type of constriction formed at the collar. On the dead straw-coloured portions two fungi were present, a *Fusarium* and a *Phoma*. The former fungus was evident in the form of pink pustules and the latter as small black bodies. Both these fungi were taken into pure culture and grown on maize-meal agar in order to test by inoculation experiments if either or both were capable of causing the disease.

Dadap seeds were surface-sterilised in corrosive sublimate and grown in pots of sterilised soil. Sixteen days later when the seedlings were from four to six inches high they were inoculated on the stems at ground level with the *Fusarium*. The inoculations were made by placing a piece of the culture medium containing growths of the fungus in contact with the stem. Five seedlings were inoculated and two were left uninoculated to serve as a control. After inoculation the pot was covered with a bell glass. A similar experiment was carried out with the *Phoma* on nine seedlings of the same age as those used for the *Fusarium* inoculations. Five of the seedlings were inoculated and the pot was covered over with a bell glass. Seven days after inoculation two seedlings inoculated with the *Fusarium* developed an olive-brown discoloration on the stems around the points of inoculation. This discoloration extended to about an inch up the stem and

pinkish pustules of spores were produced on the discoloured area. The seedlings inoculated with the *Phoma* remained unaffected. The two pots of inoculated plants which were lying on the verandah of the laboratory, exposed to sunlight but not to rain, were uncovered and left in the open. A week later, the parts of the stems which were discoloured olive-brown by the *Fusarium* had developed wounds, but in another six weeks the wounds had completely callused over. As a result of the inoculations the *Phoma* was considered secondary and of no importance, and further inoculations were made on dadap seedlings with the *Fusarium* only.

Dadap seedlings five to six inches tall and eighteen days old from sowing were raised in pots of sterilised soil for experiment. Six seedlings were inoculated at the young shoot with spore masses; they all took infection and in eleven days the shoots were killed back to about an inch. Two seedlings were inoculated on the upper surfaces of the youngest two open leaves with spore masses and one seedling on the lower surface of two full-grown leaves with drops of the culture medium containing the fungus mixed with water. Both the inoculations were successful; in the case of the former, the fungus killed the leaves, spread to the shoot and killed it back, and in the case of the latter a large area of each leaf was killed and hyphae appeared on the upper surface in woolly pinkish growths. Seven seedlings were inoculated at ground level after wounding by lightly scraping the cortex with a scalpel and applying the fungus in culture in contact with the wound, and two seedlings were inoculated similarly but without wounding and half-way up the stem. Infection occurred in every case, the stems at the region of inoculation becoming olive-brown in colour in about ten days. The bell glasses which covered the inoculated plants were now taken off and the pots were placed in the open. A few days later, the discoloured areas on the stems turned into wounds and in another month's time the wounds healed over. The diseased leaves and shoots which were killed by the fungus had fallen off and new ones had replaced them.

Dadap seedlings of the same age as those selected for the previous experiments were inoculated with the fungus in culture on the stems after wounding and without wounding and the plants were kept under a bell glass. The object of the experiment was to ascertain whether the fungus was capable of killing the plants under these conditions. Fourteen seedlings were inoculated. A month after inoculation all the seedlings showed the typical olive-brown discoloration at the points of inoculation. Fructifications of the fungus developed in the wounds of two seedlings, but a fortnight later the lesions on the unwounded seedlings had disappeared and the wounded seedlings were healing the wounds rapidly.

These inoculation experiments showed (1) that the *Phoma* which occurred in association with the *Fusarium* was secondary, (2) that the *Fusarium* was parasitic on dadap seedlings, that it could attack the stems through wounds and without wounds and it could also attack young and full-grown leaves and kill back young shoots, (3) that it was a weak parasite on dadap seedlings as it was able to infect them but unable to cause death, (4) that the fungus lived in the tissues of the host plant when atmospheric conditions were moist, as was observed when the plants were covered with bell glasses, and that as soon as the bell glasses were taken off and the pots were exposed in the open, the plants appeared to be able to resist further invasion of the hyphae and to heal over the wounds made by the fungus, (5) that it was possible that very humid atmospheric conditions were required to cause the fungus to be destructive.

Species of *Fusarium* are common saprophytes in Ceylon and are commonly encountered on dying or dead plants. The weak nature of its parasitism as shown in the inoculation experiments makes it possible that the *Fusarium* assumed a parasitic *rôle* in the present case only when favoured by suitable atmospheric conditions. Under the conditions of experiment the fungus was unable to kill seedlings. On the whole, the fungus is not of economic importance and special treatment is not required.

On maize-meal agar the fungus developed a rich growth of white, cottony hyphae, and pale coral-red pustules of spores were produced from ochraceous-brown sporodochia in a few days. The macroconidia were hyaline and varied in shape, being usually elliptical, fusoid or cylindrical-oval. They measured 6 to 12 by 2 to 3 microns. The macroconidia were hyaline, long, straight or slightly curved with falcate tips, divided by one to four transverse septa, usually three, and measured 15 to 40 by 2·5 to 4 microns. The hyphae were hyaline, septate, branched and 2 to 6 microns in diameter. Anastomoses of ordinary hyphae and of germ-tubes were of frequent occurrence. These observations were made from a culture ten days old.

Park (1) described a *Fusarium* disease of dadap associated with the dieback of branches of trees before or after lopping. On a maize-meal agar culture ten days old, his spore measurements were 36 to 62 by 4 to 5·5 microns; the conidia were four to six-septate, usually five. If sizes of spores and septation are considered sufficient to distinguish two species of *Fusarium*, the species on the dadap seedlings is different from that found by Park on dadap trees.

REFERENCE.

1. Park, M.—A *Fusarium* disease of dadap (*Erythrina lithosperma*). Ann. Roy. Bot. Gardens, Peradeniya, X, pp. 275-293, 1927.

Photo by *L. S. Bertus.*

Dadap seedlings attacked by *Fusarium* sp.

CHEMICAL NOTES (5).

ANALYSIS OF LEUCAENA GLAUCA HAY.

A sample of *Leucaena glauca* hay was recently forwarded for analysis and report on its feeding value compared with that of lucerne hay. The analysis was carried out by Mr. Panditteseker, Assistant in Agricultural Chemistry, and is quoted below. The analysis of an average sample of lucerne hay (before flowering) is shown for comparison.

	Leucaena hay.		Lucerne hay (before flowering)	
	On material as received. %	On dry matter at 100°C. %	On original material. %	On dry matter at 100°C. %
Moisture	8·89	--	16·00	--
Protein	23·28	25·56	16·2	19·29
Fat	1·97	2·16	2·4	2·86
Carbohydrates	46·51	51·04	31·1	37·02
Fibre	10·34	11·35	27·0	32·14
Ash	9·01	9·89	7·3	8·69
Nutritive ratio	1:2·2	1:2·2	1:2·3	1:2·3
Food units	104·6	114·8	73·9	88·0

It will be noted that the sample of *Leucaena* hay contains much less moisture than the sample of lucerne hay. It has more carbohydrate, protein and ash and less fibre than the latter. *Leucaena* hay has therefore more food units than lucerne hay when these are calculated on the analytical figures obtained. Its nutritive ratio calculated on the above figures is narrow and the same as that of lucerne hay. From the above it would appear that *Leucaena* hay would form a very valuable fodder for cattle in Ceylon.

ANALYSIS OF SOME CEYLON VEGETABLES.

In an article in *The Tropical Agriculturist* of April 1921, the analytical composition of some Ceylon foodstuffs and their food values were detailed by the late Mr. Kelway Bamber. Since then queries have been received from time to time as to the composition and food values of some popular Ceylon vegetables not included in that article. Analyses of these were therefore undertaken in this laboratory by Mr. Panditteseker, and the results are set down below for the information of those who may be interested.

	On material as received.									On dry matter at 100°C.				
	Moisture. %	Protein %	Fat. %	Fibre. %	Carbohydrate. %	Ash. %	Nitrogen. %	Nutrient value.	Nutritive ratio.	Protein. %	Fat. %	Fibre. %	Carbohydrate. %	Ash. %
Bandakka (Ladies fingers) *Hibiscus esculentus*,	91·82	0·94	·065	0·99	5·43	·76	·149	6·5	1:5·9	11·46	0·80	12·07	66·40	9·27
Drumstick *Moringa plerygosperma.*	89·30	2·21	·111	2·89	4·54	·95	·354	7·0	1:2·1	20·66	1·04	26·96	42·44	8·90
King yam (from Jaffna)	71·23	1·73	·032	0·62	25·43	·96	·277	27·2	1:14·6	6·02	0·11	2·14	88·39	3·34

It will be noted that of these king yam has the highest nutrient value and a very broad nutritive ratio. Drumstick and bandakka have about the same nutrient value, though the former has a much higher protein content and hence narrower nutritive ratio than the latter.—A.W.R.J.

SELECTED ARTICLES.

THE OCCURRENCE OF MYCORRHIZA IN CINCHONA IN JAVA.*

[Note.—There are two schools of thought regarding the significance of the presence of mycorrhizal fungi in the roots of plants. On the one hand, it is held that the association is for the mutual benefit of host and fungus and this theory is upheld by the fact that in extreme cases such as are found in the orchids the plant is unable to grow in the absence of the fungus; on the other hand, it is held that the condition is one of suppressed parasitism and that the host plant receives no benefit from harbouring the fungus. It is possible that there is a range of conditions from the one extreme in which the fungus is essential for the normal development of the plant to the other in which the condition is one of pure, but suppressed, parasitism.

The presence of mycorrhiza in tea, rubber and other tropical plantation crops has been noted recently. In Ceylon it has been found that apparently healthy rootlets of tea from elevations ranging from sea level to 6000 feet commonly contain fungus hyphae. A realization of their significance is of importance. If the fungus is beneficial to the host plant, then it should be encouraged. If, on the other hand, the condition is one of suppressed parasitism, it may be possible to improve the health of the plant by reducing the amount of root infection. It is conceivable that, if the condition is one of suppressed parasitism, a factor which reduces the vitality of the plant will lessen its resistance to the fungus with a consequent increase of the degree of parasitism and the ultimate death of the plant. This may be of significance in the root-disease problem, especially since *Rhizoctonia bataticola* is one of the mycorrhizal fungi and is also found in association with the death of adult plants of tea and rubber.

In the succeeding paper Dr. Steinmann has described the mycorrhiza of *Cinchona* and has indicated their widespread occurrence in Java.]

SINCE the investigations of Frank in 1885 it has been known that the roots of certain plants can live in symbiosis with certain kinds of fungi. The fungus hyphae in many such cases, in contrast to those of parasitic fungi, do no damage to the cells of the host plant; the higher plant and the fungus live in association. The plant provides the fungus with carbohydrates which are formed by assimilation, whilst the fungus provides the plant with nutritive salts, especially with nitrogen-containing foods. Such fungi living in symbiosis with roots are called mycorrhiza. There are two types of these. In the first the fungus forms a sheath around the root, and such are known as ectotrophic mycorrhiza. In the other the fungus hyphae are found inside, in the cells of the roots. These are called endotrophic mycorrhiza.

Janse was the first to examine a number of plant roots in Java in order to determine the presence of mycorrhiza. He gave in the *Annales du Jardin Botanique (Buitenzorg)* a complete list of plants (mostly those of the high

* By Dr. A. Steinmann in *Overdruk uit Cinchona*, 5, Nos. 1-2, November, 1928. Translated by H. Ludowyke, Librarian, Dept. of Agriculture, Peradeniya.

forest of Tjibodas) on which he had found mycorrhiza. Among these was cited a cultivated plant, coffee. Von Faber noted the presence of mycorrhiza in the roots of various "crater plants" (especially *Ericaceae* and also *Ficus diversifolia*) and at the same time showed that the intensity of the invasion of fungi varied and was more intensive at certain times of the year than at others. Lately I have had an opportunity of discovering mycorrhiza in the roots of healthy plants of *Cinchona succirubra* from Tjinjiroean and from Tjibodas and also in the roots of various kinds of tea such as *Thea japonica* and *Thea sinensis*.

As far as I know, this is the first time that mycorrhiza have been connected with cinchona. As regards tea, Tunstall in 1925 noted the presence of a mycorrhiza in Assam, and Malcolm Park did so recently in Ceylon. These are exclusively endotrophic mycorrhiza in which the hyphae are present within the cellular tissue of the root, whilst there is nothing extraordinary to be seen outside the roots and no definite external symptoms of the presence of mycorrhiza exist, except in certain cases in the irregular nodular swelling of some portions of the root.

The cinchona mycorrhiza were found in the thin capillary roots as well as in smaller roots of 2-3 mm. diameter. The fungus is not present throughout the parenchymatous tissue of the root cortex but only in certain places. Often these places, as has been mentioned before, may be recognised by their irregular and sometimes nodular exterior. The mycorrhizal fungus is sometimes found several cell-layers deep in the cells of the cortex, but it never penetrates into the endodermis. The sometimes colourless but mostly brown to dark-brown hyphae which often appear as globular, swollen cells are usually found in the three outermost cell layers of the root cortex. The hyphæ are both inter-as well as intra-cellular, are branched and generally 1·7-3·5 microns thick. Sometimes they show swellings; sometimes, in certain stages, the hyphae in the cells unite into bundles which again change into yellow rough, nodular masses which correspond to the bodies described by Janse as sporangioles and as disorganised remains of mycelial threads in the host plant. Especially in the cells of the roots of *Cinchona succirubra* there was a dark-gray to dark-brown fungal tissue of pseudo-parenchymatic structure which strongly resembled sclerotia. I have not yet succeeded in getting the mycorrhizal fungus in culture. In saccharose-agar nutrients of various concentrations as well as on maize meal agar there was no growth. The same sclerotia-like bodies were found also in the roots of *Thea japonica* which was growing in the mountain garden at Tjibodas.

Regarding the function of the mycorrhiza fungus there is no agreement. Its occurrence in each case, at least in Europe, seems from external appearance to be dependent chiefly on the soil.

Until the fungus is obtained in pure culture nothing can be said regarding its systematic place. One must observe in the first place whether the mycorrhiza occurs in all soils or only in certain kinds of soil. An investigation regarding its occurrence in certain kinds of soil should provide valuable data regarding the feeding requirements of cinchona and it is also not without importance from the point of view of manuring. There seems to be a primary connection between mycorrhiza and the presence of humus. In accordance with the observation of Von Faber that mycorrhiza are most prevalent in spring, developing at about the end of the rainy season, it should particularly be mentioned that cinchona and tea roots were examined in February and April and these were taken from estates of very high elevation where the external influences (namely climate and soil) corresponded to some extent with those of the *solfatare* district.

The soil there is naturally richer in free (sulphuric) acid and aluminium. In order to form an idea of the definite qualities of the soils in which mycorrhiza are met with in *Cinchona*, the pH., the exchange acidity and the hydrolytic acidity were determined and the following results were obtained.

	Exchange acidity	Hydrolytic acidity	pH
Mycorrhiza in *Cinchona succirubra* at Tjiinjiroean	2·5	47·5	5·1
Mycorrhiza in *Cinchona succirubra* at Tjibodas	1·1	25·0	6·2

For the sake of comparison there is given also the acidity of soils from the *solfatare* of Gedch taken along with the roots of *Vaccinium varingiifolium*. In the roots of this plant was found a mycorrhizal fungus which in all respects corresponded to that of cinchona at least in its external morphology as observed in the roots; pure cultures of the fungi were not available.

	Exchange acidity	Hydrolytic acidity	pH
Vaccinium varingiifolium in solfatare of Gedch	2·0	17·5	5·41
Vaccinium varingiifolium in solfatare of Gedch	2·3	25·0	5·10

In conclusion, I should also mention that Malcolm Park besides showing in Ceylon the existence of hyphae in the cells of the cortex of healthy *Hevea* roots has succeeded in rearing a mycorrhizal fungus from tea in Ceylon. It shows similar morphological characteristics to some strains of *Rhizoctonia bataticola*. Since, however, at the same time other fungi were isolated, a definite opinion now on the question whether the mycorrhiza fungus of tea is beneficial would be rash.

TROPICAL FOREST LANDS.*

SO much has been written about the presumed natural high fertility of tropical forest soils, that it might be well at this stage in the rapid development of many tropical regions, to enquire into the reasons which may or may not justify the general acceptance of the idea. There have been many instances of disappointment following attempts on the part of settlers in tropical countries to bring humid virgin soils into successful cultivation for certain crops. Things have gone very well for a few years, and then a rapid diminution in productiveness has been experienced. Mr. E. A. Walters ably discusses a particularly interesting case in his article appearing in the current issue of this journal. He has described how the forest lands of St. Lucia in the British West Indies have given very unsatisfactory results when utilized for banana growing. He attributes failure to the profound changes that have occurred in these lands since the ancient forest covering was removed. He stresses the concomitant adverse effects caused by surface erosion which leads to loss of soil organic matter, and by reduction of wind belts which results in loss of soil moisture. Anyone conversant with the agricultural development of humid tropical countries could doubtless quote similar instances of soil degradation following land exploitation.

It is not generally realised that many tropical forest soils, despite their superficial appearance of high fertility, are deficient in plant nutrients. Some years ago, the late Sir John Harrison wrote as follows about the forest soils of British Guiana. "The question has been raised as to how it is possible for the British Guiana soils, if they are so lacking in fertility as appears from chemical analysis, to support as they do a heavy forest growth. In the case of a forest, the nutrient constituents of plant food are taken up by roots which traverse a very wide area. In that of cultivated plants, the space occupied by the roots is comparatively small. Hence the trees can draw their necessary food from a relatively enormous mass of soil compared with that which the cultivated plants can utilize. The mineral constituents in the case of trees accumulate in the leaves and in the small branchlets, but little being retained in the wood of the stem. When the leaves are shed, the mineral substances are returned to the soil. Similarly, a considerable proportion of the plant food is, in the case of certain trees, returned by fallen flowers. The plant food thus returned to the soil from which it was derived, is set free by decomposition, and is again utilized by the trees. Thus it may be described as circulating and performing its functions in a practically endless circuit from soil, through the tree to its leaves and flowers, and back to the soil. The tendency in the forest is for much of the plant food gathered by the deeper roots to accumulate in the upper layers of the soil. In our tropical forest, this has taken place in the course of ages to such an extent that the trees which now flourish therein are largely surface feeders so that their roots spread through the thin layers of vegetable débris on the surface soil in a widely extending plexus. With the majority of cultivated plants, the constituents of the manurial plant food are largely removed in the products, and are thus lost to future generations of plants raised on the same soil. Hence

* From *Tropical Agriculture*, Vol. VI, No. 3, March 1929.

soils capable of supporting a long continued forest growth may, and as repeated experience during recent years has amply proved, do, when under economic cultivation, fail after very few seasons to produce crops of any value. Further, forest trees appear to flourish on soil solutions of far lower salt contents than the majority of plants of economic value can do, and it is a matter of interest to ascertain if this power of utilizing soil solutions of greater diluteness may not be due to the trees growing in symbiosis with some of the fungal organisms with which the upper layers of our forest soils teem."

Dr. Ramann, the famous German soil scientist, puts the same conclusions very aptly when he writes: "The tropical forest works with a small capital of nutrients and a rapid turnover," so that "a small amount of nutrient circulating quickly suffices for the maintenance of luxuriant vegetative growth."

There is urgent need at the present time for detailed investigation into the genesis and evolution of humid tropical forest soils, and of the effects of man's interference with the natural processes that have given rise to them. In recent years, extensive study has been made of the part played by climate in the evolution of soils. So far, however, the work has been confined mainly to temperate and sub-tropical regions, notably Russia, Germany and the United States of America. The most comprehensive statement of the principles of this new branch of soil science is due to the Russian investigators. Their generalizations are now being assiduously tested and applied in the United States and, to a lesser extent, in Great Britain.

The scientific investigation of tropical soils has only just begun. Until considerable headway has been made, it is more than likely that wasteful and unremunerative exploitation of virgin tropical land will continue unabated, and that many further mistakes will be made. It is not sufficient merely to apply the results of accumulated knowledge of the properties and behaviour of well-established cultivated arable soils. It would indeed be entirely futile to do so, for, whereas in cultivated agricultural soil the components of the soil proper have been more or less thoroughly mixed by repeated tilling, natural undisturbed soil shows a gradual transition from the surface downwards, often over a considerable distance. There is no distinct subsoil, and the natural vegetation pushes its roots to different depths depending on its botanical composition. Thus, some of the vegetation may be rooted exclusively in the surface layer of leaf débris, whilst other species may have their root systems developed in underlying soil strata, or even in the parent material itself.

It is evident that an entirely new technique will have to be elaborated for the examination of undisturbed tropical forest soils, and that experimental areas will have to be studied in detail before any general rules can be formulated for their successful utilization in agriculture. Different districts will have to be taken entirely on their merits, always with the view-point of their adaptability or otherwise to the growing of any specific crop.

It is from this aspect that a study of tropical forest soils has recently been inaugurated at the Imperial College of Tropical Agriculture. So far, the work has been confined mainly to old established cacao lands in Trinidad. These comprise forest regions that have been adapted to the growth of cacao under tree shade with little disturbance of the original soil beyond that caused by the construction of surface drains. Areas of different ages with reference to the time when they were first planted in cacao are being compared between themselves and with adjacent areas still under virgin

forest. Further comparison with areas that were once under cacao and are now growing sugar-cane is possible, and may form a continuation of the present investigation.

The method of soil examination consists in the laboratory study of soil samples obtained at different depths from the surface in holes especially dug at selected sites. The profiles exhibited by the sections are described; their natural differentiation into conspicuous strata is noted; the thickness of each of these strata is measured, and finally, soil samples representative of the individual layers are procured. In the laboratory, quantitative determinations of such factors as degree of acidity or of alkalinity, content of soil organic matter and of humus, mechanical composition, concentration of total and specific soil nutrients and calcium carbonate content are made on each of the samples of soil.

Trinidad appears to be especially suitable for studies such as these because of its diversified geological structure, its varied topography and its unequal rainfall distribution. The number of different soil types presented therein is quite large; they range from mature sedentary soils to recent swamp and stream alluvium. A considerable proportion of the land is still agriculturally undeveloped, and several forest reserves have been demarcated both in the uplands and in the plains.

From the biological aspect, much work requires to be done on the indentity and activity of various organisms that comprise the soil flora and fauna. The question of microbial nitrogen transformations in tropical forest soils is almost untouched. The possibility of tropical forest trees utilizing symbiotic mycorrhiza as absorbing organs for obtaining supplies of different nutrients is worthy of careful study. The form in which the trees obtain nitrogenous nutriment, whether it be ammonium compounds or nitrates, and whether or no the reaction of the soil environment plays a part in this relationship, still remain to be elucidated. Some information on these subjects has been accumulated for temperate forest soils, but it does not necessarily follow that this knowledge can be applied without qualification to humid tropical conditions.

Only when an accurate understanding of the genesis, composition and nutrient status of tropical forest soils has been acquired can one hope to be able to assess the potentialities of any particular tropical forest area, to predict what is likely to happen when the forest covering is removed, and to prescribe ultimate tillage and manurial treatments requisite for the formation of new types of soil suitab'e for the cultivation of remunerative crops.

To proceed with the wholesale exploitation of our tropical forest lands without at least an appreciation of these fundamental problems is to court disaster, if not wantonly to waste one of Nature's greatest gifts.

ST. LUCIA BANANA LANDS.*

OBSERVATIONS AND COMMENTS ON SOIL CHANGES IN RELATION TO TROPICAL AGRICULTURE.

THE present paper records soil changes observed when virgin forest land is subjected to exposure and climatic influences by removal of the natural vegetation and by the substitution of a temporary crop, followed by a final re-invasion of a low type of flora.

As a generalisation which holds true for most tropical countries, it may be said that tropical agriculture falls into two fairly well-defined categories; in the first, definite agricultural operations, such as tillage, fertilising, and soil improvement, are undertaken, while in the second category methods of clearing virgin forest and cropping with the minimum of cultivation necessary to plant and raise the crops are adopted, such as the firing of bush for planting roots, the digging of holes for root stocks which are merely covered with a layer of soil, and the annual brushing of weeds in established crops. Examples of both classes are of frequent occurrence in the West Indies and Central America. According to the methods pursued different kinds of biological processes will be set in motion which may ultimately become of very great agricultural significance. In short, the soil will either undergo progressive amelioration or progressive deterioration.

The writer has seen virgin land cleared for large-scale banana production, the raising of banana crops, the ultimate collapse of the industry, the withdrawal of all supervision from cultivated areas, followed by the re-establishment of a natural flora. Careful observations have been made over a period of five years, on the original soil conditions and its plant population, the exploitation of this soil under banana cultivation (which it should be noted falls into the second category as above) with a concluding survey of the present state of the soil in derelict banana lands. These observations have shown that there are certain important influences which will affect tropical agriculture conducted along these lines.

Opening of banana lands.—The Banana Company was probably the first to clear large areas of virgin forest in St. Lucia for a pure crop. New tracts of land had, in the main, been taken up cautiously and planted tentatively in a short period crop such as sugar-cane, which as a pioneer crop was utilized to break up the soil and promote a superficial tilth. One or sometimes two of the long period crops such as coconuts, cocoa or limes, usually followed in the second or third year, with plantings of bananas and other accessory crops.

There was thus little available information as to the changes resulting from the removal of the heavy and ancient forest vegetation and its substitution by a comparatively light crop, such as bananas. It is interesting to note that the large-scale physical effects occasioned by the loss of the protective forest canopy began to be obvious within two years from the

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* By E. A. Walters, F.R.H.S., F.R.Met. Soc., in *Tropical Agriculture*, Vol. VI, No. 3, March 1929.

removal of the forest, and took the form of landslides and eroded surfaces. Similar but more intensified conditions have been recently reported by Hill as appearing in Jamaica, following the replacement of forests by coffee plantations. In view of these and other instances such defects cannot be regarded as accidental but predetermined, given the coincident factors of soil formation, declivity and rainfall, with the absence of protective vegetation.

The apparent reason for the selection of forest land was the belief that it was naturally fertile and had a fairly high rainfall; there was the additional advantage that an extensive area was available for development.

Topography of banana country and climatic conditions.—The elevation of the site selected for banana cultivation was 400 feet above sea level, in a mountainous and broken region at the foot of Mt. Lacombe, a peak over 1,480 ft. high, arising from the central ridge and watershed of the Colony. The land in this area consists of a series of moderately steep slopes lying at angles of 25° to 45° mostly facing west and north and forming the foot of the central ridge. In the upper areas these slopes end in abrupt banks enclosing small streams and forming shallow embryo cañons, which on lower levels widen out and expose the underlying igneous rocks forming the bed of the stream. These wider river valleys appear to be an advanced stable stage of the cañon-like formations still found in the upper areas, and represent continued erosive action of rainfall and streams in washing out the soil in the upper and middle areas and generally smoothing down the projecting land masses. Much of the soil so removed has been transported down stream and has formed to some extent the larger and fertile alluvial valleys near the sea.

The upper lands around the sources of the cañon-like streams have not yet been smoothed out, owing largely to the protective effect of the forest canopy in reducing erosion. They show no rocks or consolidated material, and where exposed by removal of the forest trees, rapidly scour away and form landslides, which precipitate the surface soil into the streams and carry it into the lower valleys. Such lands are naturally in a state of instability owing to the effect of erosion and climatic stress, and these effects are greatly accelerated by the removal of the forest canopy. One purpose of this paper is to point out how the soil is degraded and agricultural operations are interfered with, unless means are taken to consolidate the soil *in situ* before degradation has progressed too far.

The banana lands lie within a yearly rainfall contour of 100 inches, the maximum precipitation being from 4 to 5 inches in one day. High winds are usual during rain storms and in combination with the rain drops produce a drilling effect on the exposed soil, which being of a clayey nature soon becomes water-logged and insecure on its bedding of weathered soft rocks.

The fairly wide range of air temperature (from 62° to 88°) which obtains in this region is an important factor in promoting denudation of exposed sites. In the forest, however, the range is less, the maximum temperature being depressed by the heavy shade and constant high humidity. An effect of this buffer action is to reduce evaporation and retard the upward movement of soil water. When the forest vegetation is removed other factors come into play to promote desiccation, the chief of these being the absence of transpired water vapour, the depression of humidity, the formation of drier air currents and an increased range of temperature, due to exposure to the direct rays of the sun. These factors combined with direct rainfall tend rapidly to remove the accumulated humus which is not replaced by natural agencies until a crop is established or some form of vegetation covers the soil.

SOIL AND FLORA OF VIRGIN FOREST.

(*a*) *Soil.*—The soil of this region consists of weathered volcanic matter derived from the washings and denuded material of the igneous agglomerates, tufas, brecchias and grits, which have decomposed in the direction of hydrated silicates of aluminium, iron and magnesium. The soil profile is thus influenced to a great extent, both in colouring and texture by the presence of these elements, and shows all gradations from a yellowish to bright-red lateritic clay on the surface to a vari-coloured kaolinized soft rock or soapstone below. As mentioned before no surface rock is present, and where the underlying decomposed rock is exposed as in road cuttings or landslides it quickly breaks up into granular fragments in which iron oxide is conspicuous, and is thus added to the soil. The absence of gravels and rock fragments in this type of soil renders natural drainage defective and this is to some extent responsible for the peculiar changes mentioned below which follow deforestation.

(*b*) *Flora.*—The vegetation of this region is of the tropical rain forest type, and has reached a stage of dominance and comparative stability (forest climax) until artificial agencies (biotic factors) intervene. These include selective felling and general removal of timber for agricultural development. So far as can be observed no natural afforestation takes place once the climax forest is removed, and the reason is probably to be sought in subsequent soil and climatic changes. The rain forest is composed of three well-defined strata of vegetation, the upper forming a fairly dense canopy at about 80 to 100 ft. above the ground, and consisting mainly of solitary specimens of Balata, Courbaril, *Inga, Andira and Richeria,* above which rise the loftier forms such as *Sloanea, Nectandra* and *Bursera.* Below the canopy is a sub-stratum of short trees and tall shrubs, including several palms, viz., *Asclepias, Clavija, Thrinax* and *Acrocomia,* this is discontinuous and varies according to light intensity and exposure. The ground vegetation consists of short shrubs and creeping herbs, the latter only being conspicuous where the light is more intense.

The absence of any form of close-growing surface vegetation on the forest floor, such as mosses, dwarf ferns, &c., is interesting in view of the strong succession of herbs which invades an area cleared from forest. It may be due to some extent to the absence of light, although the forest bryophytes generally have but a poor light requirement. It is probable that a more definitely inhibiting factor is the loose mass of slowly decaying vegetable matter which accumulates on the undisturbed forest floor to a depth of from two to three feet in the absence of sunlight or other desiccating agencies. This layer of "raw humus" resembles the Hochmoor peat formations, typical examples of which have been found in St. Lucia in undrained low-lying land under cultivation where remains of a buried forest flora still exist in a fairly well-preserved state.

Soil conditions at time of planting.—Two main soil types will be taken as instances conforming to general conditions observed at the time of planting bananas. Soil type No. 1 was observed in planting the nursery in 1923 and soil type No. 2 in planting the hillslopes of new areas opened up in 1926. Soil type No. 1 found in the site described as the nursery in this and a former paper was part of the first area of forest land exploited by the Banana Company. The site consisted of about 200 acres of forest land lying along the north-western slopes of a moderately steep ridge running out from the foot of the central peak previously mentioned and was more exposed to the prevailing winds than land described under soil type No. 2.

The soil consisted of a brownish-yellow clay loam and was typical of the forest soils in their area. It was covered by a loose layer of forest litter, the original deposit of which had apparently decayed and brought about a

definite colour and texture change in the first three to six inches of soil immediately underlying it. The top layer was distinctly darker and looser than the sub-surface soil. At twelve inches the latter was a brownish-yellow smooth clay loam becoming more compact and tenacious as depth increased. Only the stronger primary roots of forest trees appeared to penetrate more than two feet, the principal root section being the first 18 inches as seen in the root profiles taken in this area. The soil puddled readily in wet weather but responded to aëration and liming by changing in colour from brownish-yellow to brownish-grey and forming a definite crumb structure, a change observed in the strictly localised spots where bananas had been removed and the soil limed.

Soil type No. 2 found on the westward slopes of Mt. Lacombe (previously under forest) was not exposed to the prevailing winds as was No. 1. Its characteristics differed from the former by being apparently less weathered, and with less admixture of humus, while the forest litter was rather more matted and overlaid a shallow root stratum. The soil was a yellow clay showing little differentiation with depth and in its general character appeared to be an earlier stage of soil type No. 1. This soil became very sticky in wet weather and was naturally retentive and difficult to work; no observations on liming were made as no lime was applied at any time; the effect of aëration was temporarily to granulate the soil in large particles, but these broke up again when the soil became saturated.

Method of cultivation practised on banana lands.—It now falls to discuss how these soils were treated and the nature of their response. In the first place the object of growing of bananas in the forest land was to take advantage of the fertile soil and the moderately large areas available, so that planting and cropping could alternate without a break in fruit supplies. It is thus readily understood that sites found to be unproductive would be abandoned for new land taken from the forest, rather than an attempt being made to bring the unproductive soils into bearing. A further inducement was found in the presence of Panama disease of bananas, although this disease was not confined to the unsuitable types of soil. The type of cultivation practised thus falls within the second category mentioned at the beginning of this paper.

The method of treating the forest land preparatory to planting bananas consisted of felling the forest trees, and burning or moving aside the larger logs where these interfered with planting operations. The ground was then cleared of the remaining bush and holed ready for the banana plants. Contour drains were cut along the slopes to take off the surface water, and in some areas the banks of soil thrown up were levelled and planted with a legume, *Canavalia ensiformis*.

Forking and trenching was not practised as part of the cultivation programme and no manures were incorporated in the soil, as it was considered that sufficient organic matter would be supplied by the decay of forest logs. The application of lime was solely intended for destroying the chopped remains of diseased bananas.

Cultivation was thus a matter of direct exploitation and as elsewhere the first returns of the crop were sufficiently good to endorse this practice. The subsequent and rapid degradation of the soil goes to show, however, that the initial crop production was not a true index of the staying fertility of these lands when subject to intensive cropping. The latter could only continue in the presence of some natural agency which would replace the utilised plant-food and humus. In the absence of such safeguards, the regression of the fertility of the forest soil must be regarded as a natural consequence.

Progress and termination of banana planting.—The methods pursued in the earliest stages consisted of clearing and planting a stretch of land in bananas without discrimination as to soil types. It was soon found, however, that certain areas were unproductive, and the conclusion was drawn by comparison of earlier sites with present remains of cultivated areas that these unproductive soils had already been exposed and were already in a state of deterioration at the time of planting. As similar conditions can now be seen in large sections of banana fields attention may be drawn to the fact that the succeeding stages of exposed forest land can be roughly foretold by an examination of adjoining forest lands which have been subjected to intermittent cultivation without the modifying effects of cover crops and windbreaks.

The decision to end the banana industry was due to the want of capital to complete marketing arrangements and not to insufficient production. It should be added that for some time previous to total abandonment, several fairly large areas of banana land had been thrown out of cultivation through being unproductive, and a discussion of the conditions obtaining in such unproductive areas is given below.

Unproductive and derelict banana lands.—The most striking evidence of regression of soil type was shown in the nursery site previously described as soil type No. 1.

(*a*) *Regression of soil type No. 1.*—In comparing this soil at the time of abandonment, two to three years after deforesting, with that existing at the time of planting the most marked change observed was the loss of humus covering, and on a larger scale the looseness of the soil mass, evidenced by frequent landslips, whilst a further feature was the loss of the isolated clumps of forest trees at the top of the ridges.

The shallow layer of good soil had already been heavily drawn upon and now failed to support healthy banana plants, except in the pockets of good soil which remained at the bottom of some of the slopes. Exposed banks and hummocks were the first to give out and in the subsequent erosion which followed, detritus was carried down on to the good soil and effectually reduced the planting value of the lower areas.

More recent observations show that this degradation has continued until the greater proportion of the surface soil has been transported or covered up and has been succeeded by a soil type of lower agricultural value which supported a secondary flora where practically no bananas were found.

In such sites as remain undisturbed the soil characteristics are markedly different from those observed in the early stages of cultivation, and there is evidence that a definite pan formation has replaced the smooth clay loam formerly in existence. A characteristic soil profile examined in the vicinity of a small banana plant revealed several features: The plant was seen to be subsisting on the top three inches of humus, which was covered by a compact layer of *Commelina cayennensis*. The six inches of soil immediately below the layer of humus was brownish-grey in colour and of a rough, coarse structured loam in which no roots were found. The exposed eight to ten inches of subsoil below this was a compact grey and uniform silt free from fragments of loam or humus, and showing a well-defined pan formation. The general appearance of the soil, particularly the lower, suggested a thoroughly leached condition, whilst the surface mat of humus preserved from decomposition by the covering of compact vegetation suggested a podsol or peat formation.

(*b*) *Regression of soil type No. 2*—Soil type No. 2 when examined in profile at the present time showed the following characteristics.

I. Much less degradation of soil type as compared with No. 1 viz., soil-colour and texture and vegetation.

II. That vegetable mould tends to accumulate on the surface, and does not mix with the soil to form humus and cause darkening.

Exposed for a shorter period, soil type No. 2 had to a large extent retained its original forest soil characteristics, being protected by windbreaks which had been carefully preserved when clearing this area. The soil appeared as a bright-yellow clay with a high water content and no admixture of humus. A large number of bananas were still growing amongst the luxuriant vegetation which had covered this area. The roots of the bananas when examined were found to be water-soaked, with a blackening of the root tip and fine roots. These had in most cases died back after a short period of growth, and showed both fungal and insect attack. It was also noticed that few young banana plants were formed as in the normal course of succession.

A sufficient number of pH determinations were taken by the writer to fix the present reaction of the soil within the range pH 5·9 to 6·3 for the surface three inches, at 5·9 to 6·2 for the six inch sample, and 5·9 for the eighteen-inch sample. These reactions were distinctly acid, but not such as to prevent healthy growth.

PRESENT STATE OF BANANA LANDS.

(*a*) *Flora.*—Following the abandonment and exposure of the banana lands, an entirely new flora invaded and established itself on the exposed slopes. This consisted largely of weeds common in the distant lower valleys, such as might be sown by wind-borne seeds or arise from seeds expelled by birds, both groups being new to this area. These plants formed small communities existing in the shallow layer of good soil on the exposed sites and as isolated specimens scattered throughout the whole area. Most of them had shallow root development indicating a habitat alternating between drought and water-logged conditions.

A second important indication of soil conditions was the appearance of associations of *Pteridophytes,* including tree ferns, ground ferns and club mosses, with *Heliconia* spp. occupying a wet habitat on the lower slopes and ravine bottoms, where the eroded soil allowed a deeper root range. The Araliad, *Sciadophyllum,* appeared regularly as a solitary specimen on exposed slopes, where a specially adapted root system helped it to withstand the effects of erosion.

(*b*) *Soils.*—The replacement of a fertile soil by an infertile soil is still proceeding on the more exposed slopes and has been greatest in the areas exposed over a longer period (three to five years), so that these soils are at present of little agricultural value. In the areas which have not been totally deprived of vegetation and more recently worked, these changes have been less severe and the soil would respond to careful cultivation.

A detailed survey of these areas would probably reveal many local variations of soil conditions. In some, the exposed soil consisted of powdery volcanic material without quartz fragments resulting from rock decomposition, whereas adjacent areas showed similar denuded rock with fine quartz grit. The examination of road cuttings and many other exposures indicates the general nature of the soil to be as described, but the scarcity of fuller geological information on these soils is to be regretted in view of the importance of the recorded changes to agriculture, and it is recognised that this investigation merely records the main facts of agricultural significance.

CONCLUSION.

This paper would not be complete without some suggestions for the safe development of forest lands for agricultural purposes.

It has been said that there are two ways of utilising the soil wealth, (1) by systematic cultivation, where the soil is regarded as a reservoir of plant-food to be kept in good condition, with a replacement of the material taken off in the crop, (2) by progressive exhaustion, where the soil is regarded as a storehouse of plant-food to be drawn upon without consideration as to methods of replacement or the conservation of existing materials.

It has been shown that the latter method results in a rapid and progressive depression of the humus content of the soil and a loss of fertility, to a point when the soil is no longer fit for agriculture, and fertility can only be restored by the extremely slow processes of nature.

In tropical agriculture the conservation of humus is of great importance, as external conditions are largely in favour of its rapid destruction. Closely linked with the question of humus is that of soil conditions generally and these as already indicated may be such as to bring about a rapid deterioration of soil type. It is clear that such soils cannot be treated in a haphazard fashion, they must be worked or they will deteriorate rapidly, and one of the conditions of opening up land successfully is that a good standard of cultivation must be maintained.

The following suggestions appear to meet the principal difficulties in clearing forest land and maintaining agricultural conditions.

(*a*) *Felling and clearing.*—For various reasons this is usually conveniently done in the dry season as the soil is then exposed to desiccation and subsequently to heavy washing during the following rainy season. This can be largely remedied by the removal of the larger trees only, allowing growth of vegetation to cover and protect the exposed soil and surface humus. This can be followed up by the cutting of bush and final clearing on the approach of the wet season and planting time; areas not required for planting being left for the protective covering of vegetation, which can be subsequently cut for mulch or manure-making.

Where the soil is not protected by a planted crop a green manure crop such as *Crotalaria* or *Tephrosia* could be sown to replace native weeds. Burning bush is unnecessary and wantonly destructive.

(*b*) *Shelter-belts.*—It is highly important to protect forest land by reserving a series of shelter-belts of trees of moderate height at the time of felling. The belts should run across and *not down* the slopes, so as to hold up erosive action and modify wash.

Tops of ridges should also be left with a crown of trees of moderate height, as the larger forest trees are unsafe and invariably die when exposed. All belts should be strengthened by planting Galba or *Gliricidia,* both of which can be pruned.

(*c*) *Drainage.*—This should be attended to in the early stages to prevent the formation of many new channels and consequent landslips. Main drains should be carried along the upper and lower edges of the shelter-belts at a distance of about 15 feet from the belt, and should outfall into a natural ravine or gully which should be kept open. Planting could take place on both sides of these main drains so as to economise space. Secondary and crop drains can be decided upon as a full drainage scheme is developed.

(*d*) *Terracing or banking.*—The method of terracing on slopes is an important preventative of wash and facilitates cultivation and transport (a high proportion of the bananas in the Canary Islands is obtained from terraced fields). Terraces may be conveniently formed in the first instance by half embedding the heavy logs in a direction at right angles to the slope, so that soil and humus accumulate against the upper side of the log and can be consolidated by planting the crop, by green manuring, or by allowing short leaves to cover the surface. The width of each terrace may be determined by the steepness of the slope, a sharp slope requiring more terracing than a gentle slope, and it is not necessary that the terrace itself should be level as a moderate fall will facilitate run-off.

Following these initial operations (if the economic situation will permit) the land may be trenched, sub-soiled and manured, with applications of lime, as indicated by the "working" of the soil and reaction of the crop, and the more ordinary operations of cultivation may be introduced provided the soil is not unduly exposed thereby. Methods of openworking flat lands are not applicable to sloping forest lands, and it is considered that the above suggestions, if carefully carried out, will go a long way towards preventing soil deterioration and infertility.

SUMMARY.

1. This paper discusses the effects of deforestation and exposure of tropical forest lands, with particular reference to recent banana lands in St. Lucia observed to deteriorate under commercial exploitation.

2. The conditions of exposure, the effects of erosion, the sequence of soil changes and types of vegetation are described as evidence of soil degradation and loss of agricultural value. It is shown that the agricultural development of forest lands is a special case requiring special technique for the preservation and maintenance of the natural high fertility of such areas. Concluding suggestions are made for the improved treatment of forest lands by dividing the exploited area into self-protective blocks, with the use of shelter-belts and special drains, and the conservation of the soil humus by cover crops and crop production on terraced slopes.

THE TEA INDUSTRY IN JAVA.*

THE introduction of tea into Java and the subsequent development of the industry was along lines parallel to those followed by the industry in India. In about 1690, Camphuys, the Governor-General of Java, planted the first tea in that country purely as a matter of interest, just as Captain Kyd did in India, in about 1780. In 1728, the Dutch East India Company seriously considered the planting of tea in Java as the British Company did in 1788. Neither of these schemes was carried through and it was not until 1825 in Java and 1835 in India that tea, as an industry, may be said to have started.

In 1825, the Dutch Government ordered tea seed from Japan through the renowned expert on things Japanese, von Siebold, and during the following years increasing quantities of both China and Japan seed were imported into Java.

In British India, tea plants were brought from China in 1835 and planted at Kumaon. This step was activated by the fact that the monopoly of the tea trade with China, previously held by the British East India Company, expired in that year. Although Bruce had discovered tea growing wild in Assam in 1823 it was not until a scientific deputation had visited that country in 1835-36 that the tea project moved thence.

The industry in Java did not advance so steadily as in North-East India, for it is only comparatively recently (from about 1900) that Java teas have become an important factor in the world's tea market.

In 1832 the Dutch Government, realising the possibility of tea as an industry, brought expert tea makers from China to work in Java. The results were not successful. In 1838 an establishment for the finishing of tea was established in Batavia, presumably in accordance with Chinese methods. Owing, however, to difficulties of transport, the final treatment was often not given until several months after the preliminary manufacture, and this naturally caused serious deterioration in the quality of the product. The result was that the tea was sold at a loss which, between 1835 and 1860, became so serious, that the Government abandoned its direct connection with the industry as existing contracts expired.

In 1865 several estates were rented to private individuals in the Preangers and others were opened out. The quality of the tea, however, was still inferior and could not compete with that of British India. In about 1878, hand manufacture was replaced by machinery and considerable improvement in quality was thereby effected.

Assam seed was first imported in 1872 although the first real success with this seed was not obtained till 1878. It is reported that Assam seed was imported from Ceylon to Java as early as 1877, but as the plant proved scarcely different from Java or China tea, the experiment was given up. During the tea rush in the 'eighties, more Ceylon seed was imported with no more encouraging results than before. The Assam plant has been so successful in Java that it has now become the standard type in the island.

* By C. R. Harler, B.Sc., F.I.C., in *The Quarterly Journal* of the Indian Tea Association, Part 1, 1928.

In 1882, the society known as the Soekaboemi Agricultural Syndicate was formed with the object of looking after the interests of the tea and allied industries in Java. During the 'nineties the Government took a great interest in tea and deputations visited India and Ceylon, which led to changes in Java methods. In 1902, a Tea Experimental Station was established by Government.

The growth of the industry is illustrated by the exports during the last quarter of a century.—

1901 export	...	...	16,750,000 lbs.
1905 ,,	...	...	25,500,000 ,,
1910 ,,	...	...	40,000,000 ,,
1915 ,,	...	...	101,600,000 ,,
1920 ,,	...	...	93,700,000 ,,
1925 ,,	...	...	94,800,000 ,,

The break from the steady increase in 1920 was due to the post-war slump in tea prices, following on a period of over-production. Exports are now again steadily increasing and at a much faster rate than those from either India or Ceylon. In 1925, Java and Sumatra exported over 111 million pounds; in 1926, over 136 million pounds and in 1927, over 145 million pounds.

At the end of 1925 there were 194,439 acres under tea in bearing in Java, and 26,621 acres in Sumatra, although in the latter country about 32,000 acres were planted. Of the 285 tea estates in the Dutch Indies, 260 are in Java and the remaining 25 in Sumatra. Although there is practically no more land available for tea cultivation in Java, extensive tracts in Sumatra have been found suitable for tea. In 1911, only 500 acres were planted in this latter island, but the success was such a signal one that the area has steadily increased. Most of the Sumatra estates are on the east coast, but areas on the west coast are now being fast opened out. The annual tea output of Sumatra is at present about 18 million pounds, and a great increase is to be expected in the next few years.

In 1926 the yield per acre was about 700 lb. tea in Java and 650 lb. in Sumatra, against about 600 lb. in North-East India.

The position of the tea crop from the Dutch Indies in the world market may be gauged from the export figures shown by the principal tea countries during 1926.

British India	...	...	337 million lb.
Ceylon	...	...	207 ,, ,,
Java	...	...	118 ,, ,,
Sumatra	...	...	18 ,, ,,
China	...	...	111 (?) ,, ,,
Japan	...	...	23 ,, ,,
Formosa	...	...	22 ,, ,,

Regarding the price of Java teas, it is difficult to get a direct comparison with tea from other countries, since only part of the Java crop, and that probably, on the whole, the poorer part is sold in London. Many estates sell their better grade in Batavia and Amsterdam. The table below shows the average prices for the 1926 crop obtained in the London sales.

			s. d.
North India	...	...	1/5 ·68
South India	...	...	1/5 ·62
Ceylon	...	...	1/8 ·09
Sumatra	...	...	1/4 ·56
Java	...	...	1/0 ·83
Nyassa	...	...	1/1 ·24

The individual districts in North-East India for the same season made the following averages.

			s. d.
Assam	...	...	1/6·38
Darjeeling	...	...	1/9·24
Dooars	...	...	1/4·38
Cachar and Sylhet	...	...	1/2·54

The London prices flatter somewhat the quality of Indian tea as a whole for, generally speaking, the better teas are sold at home and a greater proportion of the poorer teas are sold in Calcutta.

However, making allowances for these facts, Java teas are undoubtedly inferior to Indian teas, although not to the degree shown by the London values. Many reasons for this inferiority have been given. One is the fact that there are about 60,000 acres of *Kampong* (Malay, village) and native tea plantations. These areas are generally put out without a factory and the leaf is sold to gardens with factories. *Kampong-blad* (village leaf) is bought, usually, when the market is strong. *Kampong* tea is generally poorly cultivated and roughly plucked, although some of it, contiguous with European-owned estates, is very good, well-tended tea. The price paid for *Kampong-blad* varies and may be as much as 10 cents per ½ kilo (Rs. 9 per maund).

Another factor tending to lower the average price of Java tea is the sale of a rough grade, known as Bohea. This is only a small proportion, less than 5 per cent. perhaps, but it brings a very small price and lowers the average.

It is estimated that about 6½ million pounds of tea are consumed annually in Java. Garden labourers drink mostly Bohea. Of the tea exported, about 95 per cent. is shipped from Priok, the port of Batavia. The tea is exported mainly to Great Britain, Australia, Holland and the United States. Below is shown the distribution in 1925 of both Java and Sumatra teas.

	Java tea lb.	Sumatra tea lb.
Great Britain	39,475,000	4,745,000
Australia	32,968,000	3,067,000
Holland	19,650,000	5,381,000
United States	6,187,000	1,054,000

In 1905 it was decided to make a determined effort to improve the quality of Java tea and to this end a committee of leading planters, directors of planting companies and others interested in the tea industry suggested the formation of a Tea Expert Bureau. In 1906 an Englishman was employed to help the planters to make the best of their tea. The expert had an office first at Soekaboemi and, later, at Bandoong from which towns he reported on tea samples and visited gardens. There is no tea market in Batavia comparable with those in London, Calcutta or Colombo, but European buying firms have established themselves there and buy much tea by private contract. However, owing to the sellers having insufficient knowledge of the commodity and being out of touch with European markets, these contracts were not always, in the past, to the best advantage of the producer. Accordingly, in 1910 the Vereeniging "Thee-Expert-Bureau" took on its present form and moved to Batavia. The expert is British.

Only Dutch firms belong to the Bureau, for British agencies have their own tea tasters. At present 165 estates in Java and Sumatra are served by the Bureau, these including Arab and Chinese owned concerns,

Most of the Java tea is sold forward on the f.a.q. basis and it is the duty of the expert to see that the quality keeps up to the mark and to report any change of grade or shortcoming in the tea. In case of a dispute, the expert can act as arbitrator with two others.

The Bureau costs 60 to 70,000 guilders (£5,000 to £5,833) per annum, this sum being raised partly by a contribution of 10 cents (2*d.*) per 100 kilos (220 lb.) of tea made, of a charge of 25 cents (5*d.*) per sample tasted, and of an annual charge of 50 guilders (£4-3-4) for circulars on prices, reviews, etc. From the sum raised, £1,000 is set aside for propaganda, which is used in advertising in American papers and journals.

The tea gardens of Java are run by agency houses much in the manner as in India. The managers and assistants on the estates are practically all Dutch. The salaries paid to tea planters are about the same as in North-East India, but home leave is given less frequently. Commissions are higher than those usually given in North-East India.

The labour on Java tea estates is obtained locally, although in Sumatra it is recruited on contract from Java. In Java there is somewhat under one cooly an acre on the estate, but this figure varies widely. The labour is paid a rather higher wage than in North-East India, although the difference in cost of living may or may not account for this apparent extra remuneration. The cooly lines are well built and, on the whole, the standard of living is much higher in Java than in India.

THE TEA EXPERIMENTAL STATION.

The earliest scientific work on the subject of tea in Java was done by van Romburgh, Lohmann and Nanninga from the early 'nineties onwards, contemporaneously with that of M. Kelway Bamber in Assam and Ceylon. This work was carried out in the laboratories at Buitenzorg, connected with the famous Botanical Gardens. In 1902 the Theeproefstation (Tea Experimental Station) was founded, with Nanninga as the first Director. In 1907, Dr. Bernard, formerly of the Botanical Gardens, took over the Directorship and he still holds this post. The present staff consists, in addition to the Director, of two chemists, one botanist, one mycologist, one entomologist and three agriculturists.

The annual cost of the Tea Station is about 150,000 guilders (£12,500). A fine new stone building consisting of laboratories, offices, library, etc., comprising about 25 rooms, large and small, has just been erected some distance from the old laboratories at a cost of about 150,000 guilders.

In 1926 several associations were amalgamated and a central association consisting of a General Agricultural Syndicate for rubber, tea, coffee, cocoa and cinchona was formed. The money for scientific work will be raised by a cess of 2 guilders 20 cents per hectare (about Re. 1-2 per acre). Under the the previous system the money for the Tea Experimental Station was raised by a cess of about 20 cents (9 annas) per 100 kilos (220 lbs.) of tea produced. The cost of the Scientific Department at Tocklai works out at less than 8 annas per acre, owing to the fact that the annual expenditure, which is at present about £18,000, is borne by a much larger industry in India than in the Dutch Indies.

There was no tea for experimental purposes on the old Theeproefstation, but experiments were made on Pasir Soerronge, a garden some miles away. At the new station about 8 acres will be planted with tea and the nurseries are already put out (April, 1926). It is expected to have a larger area for planting eventually. At Buitenzorg, about 30 acres of land are devoted to green crops. This area is very fine and is managed by the Theeproefstation, although in 1928 it reverts to the Government

Agricultural Department. There are many isolated areas in the jungle, mostly at Tjinjiroean, on the Pengalengan Plateau, devoted to the work on tea selection.

The Theeproefstation published a quarterly journal, "De Thee," which reached its seventh year, and also "Mededeelingen" or reports on subjects concerning tea, as occasion arose. Between 1909 and the present, over eighty of these reports had been issued. Previous to 1907 the work on tea appeared in the journal of the Botanical Garden at Buitenzorg and in the Agricultural Reports. The scientists of the Theeproefstation published many of their purely scientific works in European journals.

Since the formation of the General Agricultural Syndicate in 1926, mentioned above, the two series, "De Thee" and the "Mededeelingen van hot Theeproefstation," will be published in the "Archief voor de Thee Culture."

TEA SELECTION.

The work on tea selection was first started in Java in 1910 by Dr. Ch. Bernard, Director of the Experimental Station, in a small garden set up at the Government Cinchona Plantation. Other gardens were put out in the jungle on the Pengalengen Plateau and, as the work of type selecting grew, Dr. C. S. Cohen Stuart took over in 1913 and began to study the principles of tea selection and problems connected with propagation.

The peculiar interest in tea varieties which we have in Assam must be an excuse for the somewhat lengthy discussion on selection which follows.

When the East India Company decided to bring tea from China in order to grow it in India, and whilst C. G. Gordon was actually on his way from China in 1834, the report came through that tea had been discovered growing wild in Assam. Bruce had originally, in 1923, found tea near Sibsagar.

The first plants from China were put out at Kumaon and Dehra Dun, but since tea had been found indigenous in Assam, China plants were also put out in that province. The commission of botanists consisting of Wallich, Griffith and McClolland which was sent to Assam in 1835-36 found tea growing wild in many places, including Kutchu, Negrigram, Nadua, Tringri, Gabru-Purbat and Borhat, besides in the hills between Assam and Burma and at Bhamo on the Irrawaddy. It was concluded however that the Assam tea was a culture variety of the China bush, which had reverted by growing in a wild state. The importation of China tea was therefore not considered harmful to the indigenous plant but was, indeed, considered desirable. This erroneous conclusion did much to introduce confusion into the tea strains of Assam which makes selection at present so very difficult.

When Cohen Stuart came to the problem, one of the aspects considered was that of the probable original home of the tea plant. A hypothesis has been but forward that, since the original tea areas are situated along several large rivers, the Yangtse-Kiang, the Hsi-Kiang, the Song-Koi or Red River, the Mekong, the Salween, the Irawaddy and the Brahmaputra, and since these rivers or their tributaries spring from the complex mountain system, conveniently termed the Anti-Tebetan range, to the east of Tibet these mountains represent the original distribution centre of the tea plant and its allies. This hypothesis is refuted by Cohen Stuart and it is suggested that the China plant arose independently of the large-leaved varieties and developed amidst the other Camellias and Theas growing in China, to which it shows a much closer resemblance than to western tea forms. China proper has a flora which is much more its own than is the widely distributed flora of Indo-China, Burma and Assam. Thus there is a large-leaved India tea plant in Manipur and a large-leaved China tea in Yunnan but no large-leaved tea plant in China proper.

Having decided that the large-leaved varieties of tea may have spread from the Anti-Tibetan range, Cohen Stuart goes on to study the transportation of the tea plant by man. Tea plants have been found near the important caravan roads between China and India. The transportation and hybridisation were generally east in Sy-Chuan, south in Yunnan and west in Burma. The typical Chinese plant has suffered less blending than the other varieties and has remained comparatively true-bred. The tea in the Shan States of Burma and Siam is the most hybridised. Assam indigenous tea has also been subject to changes from without. On the other hand it seems that Manipur, Cachar and Lushai tea, which differ so much from the other large-leaved varieties, have been preserved from the taint arising from migration.

The confusion regarding the systematic botany of tea has been largely cleared up by Cohen Stuart. Linnaeus in his *Species Plantarum* (1753) formed two genera, *Camellia* and *Thea* and, at that time, two species of *Camellia*, viz., *japonica* and *sasanqua*, were known, and one of *Thea*, viz., *sinensis*, the tea plant. In 1762 the two varieties *Thea viridis*, the plant giving rise to green tea, and *Thea bohea*, that giving rise to black tea, were distinguished and the term *sinensis* was dropped. Later it was shown that both green and black tea were made from the same plant, which was then called *Thea bohea*. Confusion started from this time and increased as each botanist worked on the problem. Sir George Watt, the most notable botanist in connection with tea during the latter part of the nineteenth century, distinguished two varieties proper, viz., *viridis* Watt (large leaved) and *lasiocalyx* Watt (small leaved). From these two, other varieties *stricta*, *bohea* and Ceylon hybrid, were considered to be derived by hybridization.

Later botanists have decided that two separate genera for *Camellia* and *Thea* species are no longer necessary and the combined genus is known as *Thea* since this name was the first mentioned by Linnaeus. Only one tea species *Thea sinensis* (L.) Seem, is now recognised. The designation is somewhat unfortunate from the geographical viewpoint since it suggests China tea.

There exist, however, at least two morphological groups of tea plants, one of which is indigenous to China, the other to India, whilst there is, according to Cohen Stuart, not the smallest evidence supporting the idea of any direct genetical or genealogical affinity connecting them.

To a great extent it is a question of convenience whether we speak of species or varieties, and the question ought not to be vested with undue importance. Within the species Cohen Stuart recognises four main groups.

Group 1, China, variety *bohea*.—Small leaves, 1½-2½ inches long, leaf stiff, leathery, usually deep coloured with 6 to 8 pairs of veins which are not very prominent; leaves usually without a definite apex. This group occurs in East and South-East China and Japan.

Group II, variety *macrophylla* v. Siebold.—Large leaves up to 5½ inches long. Trees up to 16 feet high. Number of veins about 8 or 9; no leaf apex. Occurs in Hupeh, Sy-Chuan and Yunnan.

Group III, Shan form, perhaps related to "Assam" tea.—Large leaf, up to 6½ inches long. Trees 15 to 30 feet high. Leaf light-coloured with about 10 pairs of veins and continuous apex. Occurs in Tongking, Laos, Upper Siam, Upper Burma (collectively known as "Shan" lands), possibly also Assam.

Group IV, variety *assamica*.—Very large leaves, 8-12 inches and even up to 14 inches in length. Trees up to 60 feet high. Leaves comparatively thin and flaccid, moderately dark green, with 12 to 15 pairs of veins, which are very prominent and result in the striking wrinkling of the leaf surface; moderately long, sharply defined apex. Occurs in Manipur, Cachar, Lushai.

Cohen Stuart has shown that tea is cross-fertilised and that flowers only self-fertilise with difficulty. The significance of this is that the seed from any bush may give a hybrid plant, unless care is taken to ensure that the pollen from bushes of the same variety only is available for cross-pollenization. A wasp has been noticed carrying the pollen in Java.

The need for putting seed gardens in isolated places thus becomes apparent, and the need for keeping our varieties pure is obvious. Cohen Stuart writing on tea in India says: "Carelessness about the variety of tea planted, carelessness about the precious wild tea tracts, carelessness about the management of seed gardens, carelessness, in short, about all measures that are liable to ensure an effective tea selection, such, I regret to say, has been the happy-go-lucky attitude of the British planters towards a matter that could not indeed yield immediate profits, but should undoubtedly have done so at one time or another. Nor did they lack good counsel, for Sir George Watt has, ever since 1882, endeavoured to reorganize the Assam seed gardens."

How far the rebuke is merited, it is difficult to say for, on Cohen Stuart's own statement, there has been hybridization in the Assam seed tracts for some time. We know too the Burma tea seed, brought from thick jungle, far removed for any modern cultivation, gives plants of widely different characteristics. It is thus probable that hybridization had been going on long before the planter came to Assam.

From the seeds of commercial jats as used in Assam and exported to other tea countries, the botanists in Java set about selecting pure strains. With this object 22 areas in the jungle at Tjinjiroean, on the Pengalengan Plateau, each isolated from the others by a walk of at least ten minutes, were selected as sites for seed gardens. The altitude of these areas varies from 5,000 to 6,000 feet and some areas are at 6,500 feet. Each seed garden occupies an area from about 1½ to 2½ bouws (2·6 to 4·4 acres). Of the 22 areas, 19 were put out from jats imported from India and three from Java-grown seed. The Indian seed includes the commercial varieties or jats known as Ghoirali (two areas), Rajghur sometimes called Dr. Watt's variety (two areas), Ghairhatta, Mitanguri, Singlo Hill (two areas), Jaipur, Bazaloni, Itakhuli, Nakhati, Manipuri, Kalline, Alyne, Dhonjan, Kutchu, Goipani and a pseudo-Itakhuli, from Itakhuli stocks with Ghoirali scions. The Java seed includes Tjiliwong, Malabar and Kiara Pajoeng.

The nurseries were planted out 15 cms. (6 ins.) square. At two years the plants were carefully selected for jat, regularity of branching, height, freedom from diseases like brown blight and pink disease, and were then replanted six feet apart. Four years after replanting, *i.e.*, six years from seed, a second selection was made according to jat, freedom from *Corticium* and root diseases. In the seventh year from seed, a third selection was made and in the eighth year still another.

By this method of stringent selection, only 250 trees were left in the 22 gardens, and these were used as parent trees in the grafting work which followed. As planting was begun in 1914, the parent trees are now 14 years old. The Ghoirali clearance showed the most parent trees with 40, and Rajghur came second with 28.

The value of the vegetative propagation of tea will be appreciated, although the possibilities are not so great as with some other crops. By means of grafts or bud grafts, a seed garden of uniform type may be obtained. In addition, by grafting, it is possible to obtain an absolutely uniform material for pruning, plucking or similar experiments.

The conversion of inferior bushes to high yielding ones has not been shown possible yet and, in any case, might not be practicable over large areas. Yet the possibility of extensive grafting is shown by the fact that

Cinchona trees in Java are usually grafts from the stock of *Cinchona succirubra* and the scion of another species, *C. Ledgeriana*. The bark of the latter contains 7 to 10 per cent. quinine whilst that of the former only contains 1 to 3 per cent. although the root of this species, used as the stock, develops quickly and well.

Before attempting to propagate tea vegetatively it was necessary to establish a method. In the tea seed gardens at Tjinjiroean many methods were put to the test, viz., crown cleft and splice grafting, layering, inarch and upright stem layering, and various kinds of budding and veneering. The results showed that crown grafting, budding and upright stem layering were the best, and a brief reference to each of these three methods may here be made.

Crown grafting.—The crown grafting is best made on a six or seven-year-old stock, which is sawn off some inches from the ground and allowed to grow three or four strong shoots. After eighteen months or two years these shoots, which should not be less than 4 to 6 cms. (1·6 to 2·4 inches) diameter 15 cms. (6 inches) above the stump, should be cut off squarely at the latter height. After an interval of one to three days, when the excessive bleeding has ceased, the grafting is done. Young plants, two years old in the nursery, may also be grafted by inserting the scion on the stem itself instead of on a two-year-old shoot from the stubbed stem, as in other cases. Direct grafting in this manner is however less successful than the other.

The scion used in crown grafting must be a vigorous young shoot, the best ones being obtained from 7 to 12-year-old trees, which, during the rainy season may yield as many as 50 to 150 scions per month. The best scions are the top shoots of the main stems. These young shoots are cut 20 to 25 cms. (8 to 10 inches) long and the leaves cut back to 2 cms. ($\frac{3}{4}$ inch) leaving the buds in the axils. They should be grafted as soon as possible, but if kept in a damp place wrapped in moss or ferns they may be kept for two days. The part of the shoot between the fourth and eighth leaf cutting from the tip, is made use of for cutting scions.

The stage of development of the buds of the scion is of great importance. They should be at that stage when their tegment leaflets are standing quite apart whilst the top of the young bud should be clearly visible between the expanding bracts.

Before fixing the graft, the top of the sawn stock is made smooth with a pruning knife. At the top of the stump a smooth portion of the bark, without dormant buds, is chosen for inserting the graft. The graft is bound to the stock by very thin strips of damp bamboo, and the mounted graft is carefully covered with wax consisting of resin, 10 parts, suet, 2 parts, paraffin wax, 1 part.

After grafting, young shoots growing from the stock must be cut away every few weeks for the first few months. The grafts should be shaded.

Budding.—Budding may be done on the main stems of two to four-year-old plants in nurseries or seed gardens, on the lower side branches of stumped trees or on two to four-year-old shoots of stumped trees. Budding should be carried out as low as possible on the stem or branch which must be kept free from side growth for a certain distance during the year before budding.

The buds should be taken from branches four to eight inches in circumference with a good number of dormant buds. The bark of the budding wood should not be thin, and should be at least as thick as that of the stock. Only dormant buds should be made use of. The buds are cut and grafted quickly and accurately and then bound with calico and waxed.

Upright Stem Layering.—With upright stem layering, the best results have been obtained with two-year-old shoots of stumped or pruned trees. The branch to be layered is ringed and the bare cambium (growing layer of the stem) destroyed by gentle rubbing with the back of a knife. A split bamboo filled with leaf mould is placed round the cut. After about nine months the layering should have rooted and can then be severed from the parent tree and topped for planting out. Shading is necessary for a year after transplanting.

It was found that the best success with grafting was obtained from the Ghoirali, Kalline and Rajghur jats. Bazaloni was difficult to graft because of the thin cambium.

The seed gardens at Tjinjiroean as they now stand, consists of magnificent trees of a regularity and fineness never seen in our seed gardens in North-East India.

Yet, interesting and important as is the work of vegetative propagation, it has been noticed, by careful experiment, that there is practically no correlation between jat and crop and that Assam or Burma bushes with small leaves, usually assumed to be poor jat, may yield better than many of those of purer jat. Accordingly, another selection scheme is now being worked out in which scions are taken from high-yielding bushes. For this purpose grafting has been made at an estate called Pondok Gedeh from good, medium and poor bushes on to stocks in alternate third rows. Any influence due to soil is thus accounted for if enough series of rows are taken. The crops will be collected from the various rows and correlation, if any, observed between the yield of the original bush and grafting derived from scions of that bush.

THE CLIMATE OF JAVA.

The general features of the Java climate are abundant rainfall, feeble winds, high temperatures and high humidities, all factors going to make an ideal tea climate.

The monsoon as we know it in North-East India does not occur in Java. The tea areas in North-East India back up to the Central Asiatic Plateau and, in this position, receive either the hot, moisture-laden winds from the Indian Ocean, constituting the south-west monsoon, or the gentle spill-over of cool, dry air from the Tibetan plateau, as it flows during the winter to the warm areas near the equator. Although Java is subject to a change of wind as the thermal equator moves north from April onwards and another change from November on, as the Australian continent warms up, the breeze at all times of the year is a moist one, and the seasons are only marked by an increase or decrease in rainfall and not by an entirely new set of conditions as is the case in North-East India. The wind strength in Java is not great and even when the monsoon is most steady, the direction is not constant.

In Java the sun usually rises in a clear sky, or perhaps a few stratus clouds, little more than a rising morning mist, appear in the sky. About nine o'clock small cumulus clouds appear and these increase till rain comes in the afternoon or the clouds abate and a calm tropical night follows. Such days often occur in Assam during late April and in May.

(To be continued.)

DEPARTMENTAL NOTES.

PROGRESS REPORT OF THE EXPERIMENT STATION, PERADENIYA:

FOR THE MONTHS OF MARCH AND APRIL, 1929.

TEA.

THE severe drought experienced during January and February continued until the middle of March with the result that a large number of bushes died out.

The numbers of dead bushes uprooted in April are as follows :—

Plot.		Area		Number of bushes uprooted.
141	...	1	...	15
142	...	1	...	26
143	...	1	...	77
144	...	1	...	7
145	...	1	...	59
146	...	1	...	16
147	...	1	...	10
148	...	1	...	17
149	...	1	...	4
150	...	1	...	2
155	...	1	...	20
163	...	1	...	3
164	...	1	...	10
Hillside	...	8	...	200
166	...	1	...	10
Half acre	...	½	...	20

Specimens of bushes were sent to the Acting Mycologist.

The usual annual manuring of the plots under *Indigofera endecaphylla* was done in April. The cost of the operation was as follows :—

Cutting *Indigofera*	Rs. 8·13	per acre
Applying manure and envelope forking	,, 5·00	,, ,,
Replacing cover crop	,, 1·20	,, ,,

The manures were applied in March to the small manurial plots according to the scheme.

The tea shade of three plots was lopped in March.

Plot 144. Dadap gave	...	4080 lb. of green material
,, 149. Dadap ,,	...	4930 ,, ,, ,, ,,
Half acre. *Gliricidia*	...	5270 ,, ,, ,, ,,

The shade trees are spaced 16 × 16 ft. The cost of the lopping worked out at Rs. 1-20 per acre in the case of dadap and Rs. 2-40 in the case of *Gliricidia*.

RUBBER.

In the change-over experiment started on April 1st, 1926, a change over was made to the opposite side in the case of the eight groups of trees known as "no-change-over" series and also the eight groups known as "change-over-every-year" series.

A round of treatment of all brown bast cases by the isolation and scraping method was completed in March.

In plot 77 B (for budded rubber) all vacancies were supplied in April to four plants per hole.

CACAO.

A round of pruning was done in April.

The cacao year ended on March 31st, and the yield for the total area of 40 acres was found to be low in comparison with previous years.

Yield for the last six years.

Year			Dry cacao per acre cwt.
1923-24	...	...	2·24
1924-25	...	...	3·10
1925-26	...	...	5·45
1926-27	...	...	5·03
1927-28	...	...	4·41
1928-29	...	...	2·75

With regard to the manurial experiment started in 1927-28, yield figures for the first year have been obtained.

GREEN MANURES AND COVER CROPS.

At the instance of the Systematic Botanist, separate plots of the following indigenous cover plants were sown in the show plots early in April :—

Name	Description.
Shuteria vestita.	
Desmodium Cephalotes.	Shrub.
Desmodium pulchellum.	Shrub.
Desmodium triquetrum.	Erect.
Heylandia latebrosa.	Prostrate; not twining.
Mundulea suberosa.	Shrub.
Glycine javanica.	Twining plant.
Crotalaria multiflora.	Prostrate; not twining.
Stylosanthes fruticosa.	Erect or prostrate, not twining.
Phaseolus Grahamianus.	Twining plant
Indigofera glabra.	Erect.
Indigofera Colutea.	Erect.
Indigofera nummularifolia.	Prostrate; not twining.

THE IRIYAGAMA DIVISION.

The clearing of the remaining 20 acres of jungle was completed by April 30th. Preparations are now being made for the opening of the area in contour terraces in readiness for planting seed at stake in October. A cover crop of *Centrosema* will be established.

With regard to the 50 acres already planted, the position is as follows :—

Terraces.

Area with contour terraces	25 acres.
Area with individual terraces	17 ,,
Area now being completed with contour or individual terraces	8 ,,

Cover crops.

Area with a complete cover of *Centrosema pubescens* (sown May and November 1928) ...	20 acres.
Area with a partial cover (sown January 1929)	10 ,,
Area now being sown with *Centrosema pubescens*	20 ,,

Planting material

The number of rubber plants required to fully supply the 50 acres with 4 plants per hole is ...	17,300
The number of plants available in the nurseries is	10,000
The quantity of seed required to complete this area and also the remaining 20 acres is approximately	20,000

MISCELLANEOUS.

The health of the labour force has been satisfactory except for a severe outbreak of eye trouble.

G. HARBORD,
Manager,
Experiment Station,
Peradeniya.

REPORT ON A VISIT TO AMERICA IN CONNECTION WITH THE CONTROL OF CALOTERMES IN LIVING PLANTS.*

F. P. JEPSON, M.A., F.E.S.,

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I left England on the R.M.S. "Aquitania" on January 18th, arriving in New York early on the 26th and proceeding to Washington the same morning. I left Washington on February 2nd, sailing from New York on February 3rd by the R.M.S. "Olympic" and reaching England on the evening of February 10th.

The main object of my visit was to consult Dr. Thomas E. Snyder of the Bureau of Entomology, U.S. Department of Agriculture, the well-known authority on the subject of termite control, regarding the problems presented in Ceylon by the increasing injury caused to living economic plants, particularly tea, by termites of the genus *Calotermes*. Subsequently I was instructed to make enquiries in America regarding the latest development in connection with the construction of buildings in order to render them termite-proof and the results of my enquiries in this direction will form the subject of a separate report.

Before information could be sought regarding the possibility of controlling the species of termites which attack living plants in Ceylon, it was necessary that Dr. Snyder should be made familiar with the present position in Ceylon regarding these pests with special reference to the extent and nature of the attack, the efforts which had been made in the past to deal with this problem and the lines upon which future investigation was proceeding.

The extremely serious menace which these pests constitute to the tea industry in certain parts of Ceylon was emphasised as was also the very urgent need which existed for limiting their further extension, both from bush to bush on estates and from infested to non-infested estates. It was pointed out that the problem, in its present aspect, required consideration from two points of view. Firstly it was desirable that some means should be found whereby termites could be destroyed within the plants which they were infesting and secondly it was most necessary that plants liable to attack should be protected from invasion. This second condition applied not only to plants which had previously escaped attack but equally to those which had been attacked but from which the colonies might have been eradicated by any satisfactory form of treatment. The various measures which have, in the past, been the subject of trial with the object of effecting the destruction of the infesting termites in living plants, particularly tea bushes, were described and the difficulty of securing a satisfactory and economical insecticide which possessed sufficiently toxic properties to effect this end, without injury to the bushes, was fully appreciated by Dr. Snyder.

* Publication of this report was deferred until the work of the Government Analyst had shown that there was no trace of any harmful substance in the flush of tea bushes treated with Paris Green in order to rid them of infestations of termites. At its meeting in March, the Estate Products Committee of the Board of Agriculture recommended that the report should be published and Government has agreed to publication.

It is not necessary in this report to detail the various control measures which have already been the subject of experiment in Ceylon, both against *Calotermes militaris and C. dilatatus*. It is sufficient to state that no satisfactory treatment has yet been found, although some methods afford partial relief. Unfortunately, however, in the majority of cases, the damage has become so extensive by the time it is discovered that there is little hope, by the methods referred to, of destroying all the individuals which infest the attacked plant and even a few survivors are capable of refounding the colony in time. Any successful treatment must aim, therefore, not at partial reduction of the infestation, but at the complete eradication of the invading colony.

Having learnt of the measures which had been tested in Ceylon and found unsatisfactory, Dr. Snyder proposed that trials should be made with Paris Green, one of the oldest and best known arsenical insecticides. He reported that this method had recently been found most effective against certain termites which infest living fruit trees in Hawaii. The method is simple and inexpensive, a small quantity of the powder being introduced into the galleries of the invading termites. It is said that this foreign matter is at once consumed by the termites which immediately die, their dead bodies being promptly devoured by their fellows which in turn die, one fatal dose apparently persisting in this manner through an indefinite number of bodies until the entire colony has been poisoned.

The principle of this treatment is not a new one. Arsenic is known to be an active termite poison and has been in use for many years for the control of these pests, either as the toxic element of baits, mixed with sulphur to produce poisonous fumes when heated or, in a soluble form, for the treatment of woodwork liable to be attacked by termites.

Trials with Paris Green, incorporated in attractive baits, were conducted against *Calotermes militaris* in tea by the writer in 1926 with promising, though not conclusive, results.

The treatment with Paris Green alone, as suggested by Dr. Snyder, has many advantages over poisoned baits and it now remains to be ascertained whether this method is efficacious in Ceylon as it is said to be in Hawaii. Trials on a small scale have already been commenced on several estates affected by *C. militaris* and *C. dilatatus* and the results of these trials will be reported upon as soon as they are available. It is considered that bushes attacked by *C. militaris*, with their more centralized infestation and larger cavities, lend themselves more readily to this form of treatment than do those attacked by *C. dilatatus*.

Another possible method of control was discussed with Dr. Snyder and this was in connection with the destruction of the intestinal protozoa harboured by the wood-eating termites. These organisms are essential for the conversion of the wood upon which the termites feed into a suitable condition for assimilation. Under laboratory conditions the death of these organisms, following the incubation of the termites at a temperature of 95° F. for twenty-four hours, results in the death of the termites also a few days later owing to their inability to digest their food unaided. Although the possibility of putting this fact to practical advantage was a remote one, it was considered advisable that it should be mentioned, but Dr. Snyder's assurance was accepted that no hope of control could be anticipated from this quarter and the matter was not considered further.

Dr. Snyder has suggested that a close watch should be maintained for injury to living economic plants, similar to that caused by species of *Calotermes*, by other species of termites belonging to the genus *Coptotermes*. One case of such injury to tea by *Coptotermes ceylonicus* had already come

to the writer's notice and a suspected case on another occasion. As the extremely serious injury caused to rubber in Malaya is due to a species of *Coptotermes* the possibility of the Ceylon species turning its attention to rubber in this country has to be borne in mind and *Coptotermes ceylonicus* must be included among the termites which are known to attack living plants in Ceylon.

In view of the extensive area of tea which is already attacked by termites in Ceylon, it may be considered too late to suggest that prevention is better than cure, but it is not too late to intimate that this maxim has a very real significance so far as unattacked bushes in infested areas are concerned. It has already been indicated, earlier in this report, that the protection of the plants from attack by termites is desired for two reasons, firstly in order that the spread of the pests to previously unattacked plants might be restricted and secondly in order that the re-infestation of these plants which might have been successfully treated should be prevented and thus justify the initial cost of eradication.

If an effective and economical method of destroying the termites within the infested plants could be devised, the prosecution of a vigorous campaign against the pests in all plants known to be attacked would undoubtedly reduce to a very large extent, their liability to re-infestation owing to the destruction of individuals which would if allowed to remain undisturbed, constitute the colonizing flights in due course. For the same reason plants previously uninfested would be less prone to attack. At the same time allowance must be made for the non-treatment of a number of plants owing to the difficulty of detecting infestation except in advanced cases of attack, and such plants would constitute a continual source of danger until located and treated. In this connection enquiries were made in America regarding the possible use of a form of microphone in order to facilitate detection. Such instruments are in use in certain countries for similar purposes and Dr. Snyder was good enough to undertake to have a suitable instrument designed for use with termite-infested plants which will be forwarded to Ceylon for trial in due course. If such an instrument can be produced it will greatly simplify the verification of suspected cases of attack without necessitating the unavoidable mutilation which often results from an exploration for evidences of infestation by these insects.

The successful control of these pests depends, therefore, as much upon the protection of plants from invasion by termites as upon the actual destruction of ~~these~~ insects after they have gained admittance.

As regards the mode of entry into living plants it can be stated with certainty that, in the case of *C. dilatatus,* entrance to tea bushes and seed-bearers, and coffee and cacao plants, is gained by the winged forms of the colonizing flights through dead "snags" and wounds only. The point of entry into tea bushes and seed-bearers by *Calotermes militaris* is not yet known. It will probably be found to be effected in a similar manner to that of *C. dilatatus,* in which case the problem of control for both species will be identical. If, on the other hand, the older view, that entry is gained underground from bush to bush through the roots, is found to be correct the control of these species will require consideration from an entirely different aspect.

See errata p. 307

On estates situated in the zones of activity of *C. dilatatus,* the removal from the plants liable to attack of such inviting points of entry as may be present, and, still more important, the exercise of precautions against their recurrence in the future, should endow such plants with an almost certain immunity against attack by this species.

It is realized that the treatment of large wounds and cavities, such as abound on the average tea bush in Ceylon presents many serious difficulties. Opinions as to the possibility of dealing with this problem differ. It is asserted by some that the excision of dead tissue and the disinfection and water-proofing of the surfaces so cleaned, are essential preliminaries to the prevention of further decay. Others contend that the promotion of a vigorous condition of growth by means of suitable manuring will enable the bushes to develop callus growth around the edges of the wounds which will, in time, undermine and expel the dead tissue and that disinfectants and waterproof coverings are unnecessary. Which, if either, of these views is correct can only be decided in the light of time and experiment. Where the damage is long established, and especially where a central cavity extends well below ground level, the thorough excision of all dead and dying tissue, however sound this may be in theory, is an almost impossible undertaking in practice and certainly uneconomical in the majority of cases. Unless work can be the thoroughly done it is best left alone. If the end desired could be obtained by so simple a method as special manuring it would be a very practical and economical solution to this problem and it is hoped that experiments which are now in progress will indicate definitely whether or not relief can be looked for in this direction.

If cavities and larger wounds cannot be successfully dealt with, it is essential that future attention should be directed towards the prevention of fresh wounds. If, as seems probable, the dying back of pruned branches is found to be the fundamental origin of "wood-rot," the cause of "diebacks" and their prevention require investigation before there can be any hope of limiting the injury caused by, and the further spread of, *C. dilatatus*. In the opinion of the writer, the season of pruning has a very important bearing on the incidence of diebacks. It is not possible to express an opinion as to the possible connection between "wood-rot" and *C. militaris* infestation until the point of entry of this species into living plants has been ascertained.

The problems connected with the protection of plants from invasion by termites were put before Dr. Snyder in the above form and fully discussed with him. On the assumption that the information given to him, regarding the mode of entry of *C. dilatatus* into living plants, was correct he was in entire agreement with the necessity for attention being focussed upon the treatment of wounds and removal of dead snags and also the prevention of fresh wounds in the future. He was of the opinion that *C. militaris* would be found to enter plants in a manner similar to that adopted by *C. dilatatus* and considered it unlikely that entrance would be gained underground from root to root unless this insect followed a procedure entirely different to that of its near relations. Regarding the treatment of "wood-rot" he was of opinion that the removal of dead tissue could not be dispensed with and that antiseptic and waterproof coverings were necessary to protect the cleaned surface. In this connection he suggested that the possibilities of latex and solutions of scrap rubber might be investigated as wound covers. The solution of this problem was, however, a matter for local investigation, but he endeavoured to arrange a conference with the forest pathologists of the Bureau of Plant Industry of the U. S. Department of Agriculture so that the latest information might be obtained regarding pruning, the treatment of pruning cuts and tree-surgery generally. These are subjects to which a considerable amount of attention has been directed in America but unfortunately the conference could not take place owing to the absence from Headquarters of all of the officers in question.

A suggestion was put forward by Dr. C. V. Colville, Economic Botanist of the Bureau of Plant Industry in Washington, that suitable soil conditions, such, for instance, as unusual alkalinity, might render tea liable to attack by termites, and that as the termite-infested regions in Ceylon are more or less well-defined, this aspect of the problem might repay investigation.

The writer wishes to express his appreciation of the kindness and courtesy he experienced from all the officers of the United States Department of Agriculture with whom the came in contact. Opportunities were offered of meeting a large number of officials, particularly in the Bureau of Entomology and any information desired was most readily given. The writer is particularly grateful to Dr. L. O. Howard, late Chief of the Bureau of Entomology, Mr. R. C. Sascher of the Federal Horticultural Board and Mr. G. F. Mitchell of the Bureau of Plant Industry for such help and many personal courtesies. It would be impossible to conclude this report without making special reference to the exceptional kindness, help, and hospitality of Dr. Thomas E. Snyder who placed himself and his knowledge at the complete disposal of the writer for the entire period of visit to Washington.

Peradeniya,
23rd May, 1928.

THE MAYNARD GANGA RAM PRIZE.

IN 1925 the late Sir Ganga Ram, Kt., C.I.E., M.V.O., R.B., Lahore, with that generosity for which he is now so well known, handed over to the Punjab Government a sum of Rs. 25,000/- for the endowment of a prize to be awarded for a discovery, or an invention, or a new practical method which will tend to increase agricultural production in the Punjab on a paying basis. The property has been vested in the Treasurer of Charitable Endowment for the Punjab and is administered by a Managing Committee.

The interest accruing from the property is payable to the Managing Committee.

The prize is known as the Maynard Ganga Ram Prize and is to be awarded every three years, provided a satisfactory achievement is reported to the Managing Committee. It will be of the value of Rs. 3,000/- and the competition is open to all throughout the world. Government Servants are also eligible to compete for it.

Wide publicity was given in 1926 and 1927 to the proposed award by advertisements in newspapers, both in India and aboard, and by other means, and applications were invited by the 1st January, 1929. The response has, however, been extremely poor and consequently it has been decided to extend the time for submission of the applications to the Director of Agriculture, Punjab, up to 31st December 1929. The Managing Committee reserves the right of withholding or postponing the prize if no achievement of sufficient merit is submitted.

The Punjab with its many rivers, its fertile soil and warm sun, has great possibilities for agricultural development, which is of the utmost importance as practically the whole population of the province, both urban and rural, depends either directly or indirectly on its agriculture.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED 30th APRIL, 1929.

Province, &c.	Disease	No. of Cases up to date since Jan. 1st 1929	Fresh Cases	Recoveries	Deaths	Balance Ill	No. Shot
Western	Rinderpest	1456	323	160	1159	29	108
	Foot-and-mouth disease	10	...	10	.	...	...
	Anthrax	...	...	...	...	...	...
	Piroplasmosis	2	1	1	1	...	...
	Rabies*. (Dogs)						
Colombo Municipality	Rinderpest	1281	81	111	1135	35	...
	Foot-and-mouth disease	59	54	52	7	...	...
	Anthrax	...	..	...	...	...	...
	Rabies (Dogs)	12	...	...	...	...	12
Cattle Quarantine Station	Rinderpest	44	...	27	17	...	...
	Foot-and-mouth disease	33	19	33	...	..	...
	Anthrax	...	...	...	...	...	...
Central	Rinderpest	46	..	1	44	...	1
	Foot-and-mouth disease	763	90	662	2	99	...
	Anthrax	...	...	...	...	...	...
	Rabies (Dogs)	9	2	...	...	...	9
	Black Quarter						
Southern	Rinderpest	...	.	...	...	...	...
	Foot-and-mouth disease	2013	...	1921	56	36	...
	Anthrax	...	...	...	...	...	...
Northern	Rinderpest	4	...	3	...	...	1
	Foot-and-mouth disease	157	...	87	70	...	...
	Anthrax	...	...	..	...	...	...
Eastern	Rinderpest	...	..	...	...	...	...
	Foot-and-mouth disease	8006	. .	7851	155	...	...
	Anthrax	...	...	...	...	...	...
	Rabies (Horses)						
North-Western	Rinderpest	214	113	31	111	6	66
	Foot-and-mouth disease	...	...	...	...	...	..
	Anthrax	...	...	...	..	...	...
	Piroplasmosis	1	...	1	...	...	...
North-Central	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	26	..	26	...	...	...
	Anthrax	...	...	...	...	...	...
Uva	Rinderpest	...	...	...	...	...	...
	Foot-and-mouth disease	304	1	279	1	23	1
	Anthrax	...	...	...	...	...	...
	Haemorrhagic Septicaemia	1	...	...	1	...	..
Sabaragamuwa	Rinderpest	193	68	28	160	5	...
	Foot-and-mouth disease	4451	303	4064	111	276	...
	Anthrax	—	...	...	...	...	...
	Haemorrhagic Septicaemia	14	4	1	13	...	...

G. V. S. Office,
Colombo, 10th May, 1929.

G. W. STURGESS,
Government Veterinary Surgeon.

METEOROLOGICAL

APRIL, 1929.

Station	Temperature		Mean Humidity	Mean amount of Cloud 0=clear 10=overcast	Mean Wind Direction During Month	Daily Mean Velocity	Rainfall		
	Mean Daily Shade	Difference from Average					Amount	No. of Rainy Days	Difference from Average
	°	°	%			Miles	Inches		Inches
Colombo Observatory	80·9	—0·9	83	7·4	SW	89	18·66	25	+ 10·48
Puttalam	81·8	—0·4	78	5·4	SSW	88	14·89	24	+ 9·60
Mannar	84·2	—0·7	76	7·2	WSW	142	8·73	17	+ 5·93
Jaffna	83·6	—1·2	78	6·8	SSE	150	6·08	13	+ 4·11
Trincomalee	81·7	—1·7	80	5·4	SE	119	9·14	12	+ 7·16
Batticaloa	81·3	—1·9	83	6·0	E	132	3·92	12	+ 2·03
Hambantota	81·2	—0·8	82	5·6	S	191	5·81	13	+ 2·52
Galle	80·6	—1·2	84	7·2	Var.	118	9·22	22	— 0·46
Ratnapura	81·8	—0·6	78	6·8	—	—	14·46	29	+ 2·17
Anu'pura	82·2	—0·4	72	7·0	—	—	11·81	21	+ 5·14
Kurunegala	81·9	—1·5	78	8·0	—	—	21·45	25	+ 11·74
Kandy	77·9	—1·1	80	6·3	—	—	11·77	25	+ 5·01
Badulla	74·6	—0·2	84	6·7	—	—	11·21	24	+ 3·83
Diyatalawa	67·8	—1·2	84	7·2	—	—	8·61	25	+ 2·94
Hakgala	64·4	+0	85	5·6	—	—	12·07	22	+ 4·94
N.Eliya	60·2	—0·3	80	6·7	—	—	9·68	26	+ 4·09

The local thunderstorm type of rain customary in April was unusually well developed this year, with the result that the rainfall for the month has been nearly everywhere above normal, and at many places considerably above normal, several stations having exceeded their previous record for the month. The April total at Colombo Observatory, 18·66 inches, is the highest for April recorded at the site since observations were commenced there, in 1908, but has been exceeded several times by the Fort gauge, the April record at the latter station being 28·78 inches, in 1888.

The greatest excesses above normal are on the west of the hills, and in the adjoining low-country, where excesses of 10 to 20 inches are common. A few deficits below normal are recorded, mainly in the Southern Province and in the south of Sabaragamuwa.

In spite of the high monthly totals, only one daily rainfall of 5 inches is recorded, at Kitulgala.

The mean temperature has been below average, and the mean humidity usually in the neighbourhood of 80%. Cloud has been above normal, and wind strength generally below normal. Wind directions have been variable.

Seasonal forecasting in Ceylon is still in the experimental stage, but Mr. Bamford has pointed out that an inverse relationship seems to exist between the amount of rain falling in the local thunderstorms of March and April, and the monsoon rains of the following months in the south-west of the Island. The March rainfall, on the whole, showed neither marked excess nor deficit, but the heavy April rainfall suggests a weak monsoon rainfall. Mr. Bamford has also shown (see the 1927 Observatory report) that the south-west monsoon rainfall on the windward side of the hills, for the last fifty years and more, is fairly well represented by the sum of two sine curves. The prolongation of the resultant curve to 1929 indicates a monsoon rainfall about the average.

Neither criterion is, of course, infallible, but the two together suggest that an average or a deficient monsoon rainfall is more likely than one in excess.

H. JAMESON.
Actg. Supdt., Observatory.